Decision support model incorporating the influence of systematic risk project valuation application on insourcing decision making

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Decision Support Model Incorporating the Influence of systematic risk on project valuation:

Application on Insourcing Decision Making

By
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1 Foreword

Before you lies my thesis towards the influences of systematic risk on project valuations. It has been written to fulfil the graduation requirements for the Master Operations management and logistics at the Technical University of Eindhoven.

Although the last couple of months were challenging, great support and perseverance led to successful completion of my study.

I would like to thank my supervisors for their excellent guidance and support during this process. Boray Huang, my first supervisor, for his passion in the covered topic's which resulted in great support, good discussions and critical thinking. My second supervisor Arun Chocalingam for his support and input during the entire project and of course my company supervisors Nick Schillemans and Rob van Pelt. Your input and guidance, together with all support I received from our Flowserve colleagues, is really appreciated. Finally, I also would like to thank Gert Regterschot for all his support during my whole study.

I hope you enjoy your reading.

Berry van Mil

2 Abstract

Valuation of assets is in general performed in terms of free cash flows within a net present value analysis. These free cash flows are discounted with a certain discount rate to obtain their present values. Subsequently, these present values, together with the initial investment, form the net present value of an asset. However, applying the appropriate discount rate is not always that straightforward. For example, when applying the CAPM method to calculate the discount rate, within its beta calculation, returns are considered that are based on net incomes. However, the cash flows within the valuation are in terms of free cash flows. These free cash flows are subjected to different rates of risk then net income and, therefore, requires an adjusted method for calculating the appropriate discount rate. Furthermore, this study will pay extra attention to the effects of operating leverage on the systematic risk on both free cash flows and net income.

In this particular study, a real-life insourcing/outsourcing decision problem was applied in order to investigate the effects of different cost and operational structures on the systematic risk and valuation of the two different scenarios. The method applied for these valuations was based on certainty-equivalents which enabled to possibility to not only value each project independently from company-wide data but also gave excellent capabilities to analyze both the behavior of free cash flows and net income on underlying parameters such as the degree of operational, financial and depreciation leverage and all possible project betas. Furthermore, in order to establish a reliable decision advice for the company, this study was not limited by solely the cost side but also considered areas such as production, supply chain and quality. By doing so, a well-structured advice could be presented.

After performing the cost valuation, the results were in favour of insourcing the project with a significantly higher net present value for both the net income and free cash flow based valuations. Although both valuations led to the same results, the outcome of both valuations was different. The net income based valuation resulted in the highest net present value but was at the same time subjected to the highest systematic risk. Regarding the valuations towards the outsourcing situation no differences between net income and free cash flow based valuations were visible. In the figure below (Figure 1) the present values of both situations are pictured out.

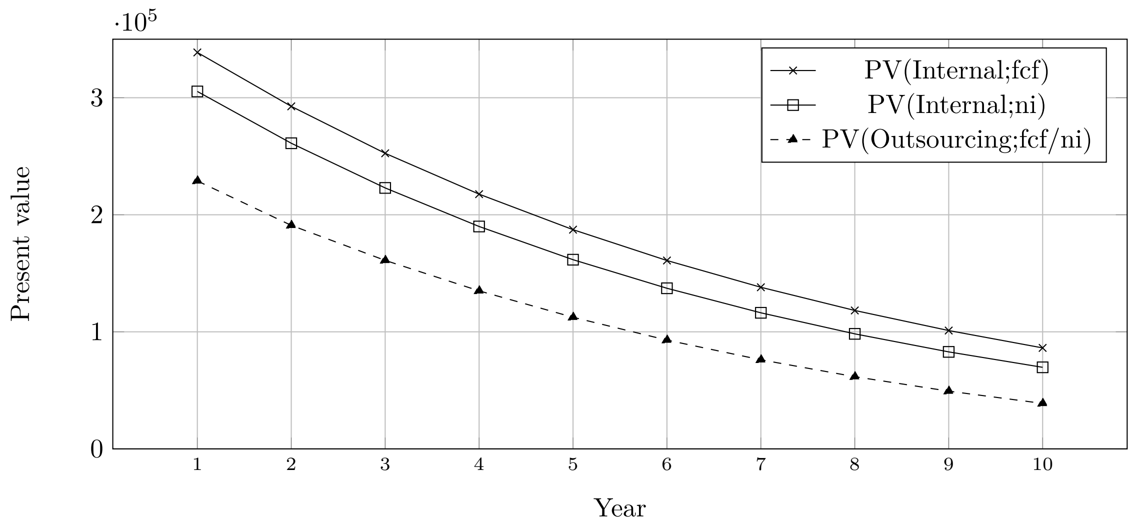

Figure 1: Free cash flow and net income based present values for in-house and outsourcing

Furthermore, the overall project outcome, including the areas production, supply chain and quality, lead to positive results in favour of insourcing. For that reason, the final decision advice regarding this project is to insource the project. The main objectives for the company to insource this project were lead time reduction, increases on-time delivery and improved quality. The corresponding area supply chain scored especially well during this study. It is, therefore, expected that all these objectives will be met during internal production. In the table below (Table 1, an overview of the scores is given.

Table 1: Scores Internal / Outsource

Score	T& MP	SCM	P	SS	Cost
Weight	25	25	25	25	100
Internal score	427	467	406	400	425
Outsource score	315	226	379	300	305
Gap	28	60	6.75	25	

Regarding the findings of the financial valuation, there were a couple of interesting findings. First of all, there is a difference observed in the outcome of the net present values between free cash flow and net income based valuations (Figure 1). Free cash flows are larger and subjected to relative less risk compared to net incomes. However, when performing a net present value analysis based on net incomes, there is no initial investment which has to be subtracted from the present values of the future cash flows. In this particular case, both valuations resulted in a positive advice close to each other. However, it is not unreasonable to think that in case of a different cost structure, a larger difference would be observed with one valuation positive and the other being negative. The second observation within the valuation is the behaviour of operating leverage in the long term. Outsourcing would initially result in lower operating leverage, implying less operational risk. However, this value would increases more rapidly during the upcoming years in comparison with internal production. Subsequently, the systematic risk of outsourcing would also increases rapidly. In the figure below (Figure 2, the systematic risk is pictured out for both situations over the entire time horizon. For that reason, it is important to consider the course of several parameters such as variables cost not only at this moment but especially in the future.

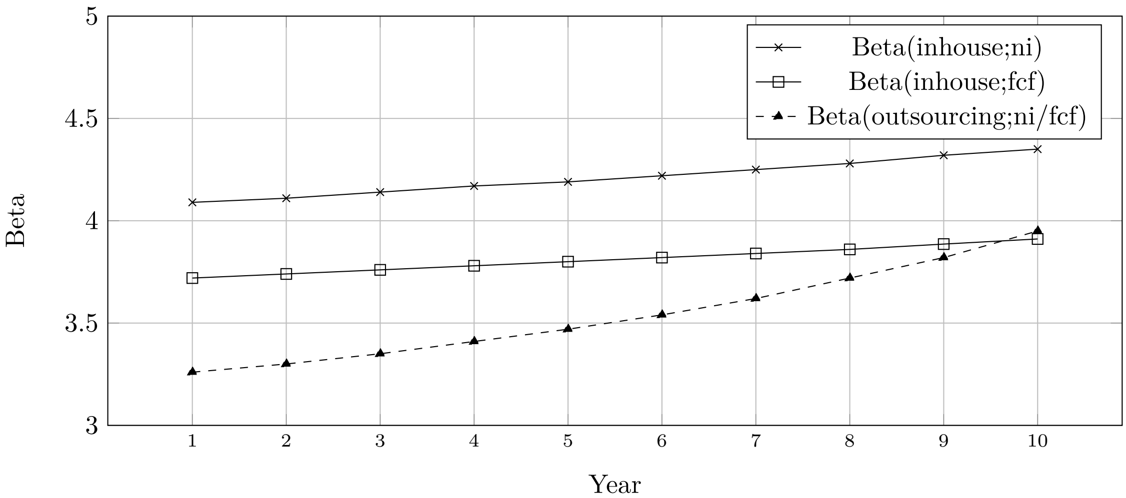

Figure 2: Project beta's (Internal production and outsourcing)

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3 Introduction

3.1 Company description

Flowserve is a leading manufacturer and after-market service provider of comprehensive flow control systems. Flowserve products are designed to withstand extreme temperatures, chemicals, intense pressures and other demanding conditions. Worldwide, approximately 16,500 employees are present at 65 manufacturer facilities and 175 after-market quick response centres (QRC's). Flowserve Etten-Leur is acting as the EMA (European, Middle-East, Africa) manufacturer HUB (central point of manufacturing), responsible for the after-market service and solutions for seals operations and pumps.

Recently, Flowserve Roosendaal, Flowserve Etten-Leur QRC and Flowserve Etten-Leur PMC (pump manufacturing centre/service and repair) merged together, forming the new Flowserve Campus in Etten-Leur. The pump division moved abroad to Italy.

3.2 Problem Statement

3.2.1 Research area

Flowserve Etten-Leur is facing a decreasing performance of outsourcing companies, responsible for the high-velocity oxygen (HVOF) overlay process. During this overlay process, a layer of hard material is added to the mechanical seal to increase durability for surfaces that are subjected to a high amount of friction and wear. Hard overlays consist of different variants, HVOF (High-velocity oxygen coating) being the type with the largest share.

The decrease in performance is observed in different areas such as on-time delivery, lead time, quality, et cetera. As an effect, Flowserve is subjected to longer lead-times and less reliability towards her own customers. Even more attention is required due to the high dependability of only two key outsource companies. Management is uncomfortable with this situation and, therefore, has questioned herself whether or not the HVOF overlay process should be performed in-house. Moreover, Flowserve expects to reduce costs and shorten lead times by in-sourcing this process. This leads naturally to the research problem of this thesis. 'Investigate the feasibility of in-sourcing the HVOF process in order to improve outsource dependability, quality and cost". By proposing a comprehensive decision model, this thesis will deliver a decision advice in which relevant factors are considered.

As a convincing justification regarding the returns of this project is required for such an investment, the focus is put on this financial part of this project. It will also be the part which is related to the academic research. Within this part, the influences of systematic risk on the valuation of the project in terms of free cash flows and net income are investigated.

3.2.2 Scope and research questions

The goal of this study is (1)to investigate the feasibility of in-sourcing the HVOF process and (2)to go more in-depth in the relationship between the systematic risk of the project during in-house and out-sourcing for both free cash flows and net income. This implies the use of an appropriate decision model, including a cost valuation. The feasibility study should deliver a robust decision advice in which all relevant factors are considered. The scope of this study is limited to the HVOF process as this type of overlay accounts for the largest share of processed overlays. According to the problem statement, the following research questions are established:

Main research question: *'Should Flowserve Etten-Leur insource the HVOF overlay process in order to reduce outsource risk, lead-times and cost?'*

In order to divide the problem into smaller, more manageable problems, the following sub-questions are formulated:

Sub-question 1: *What are important factors during a decision process?*

Sub-question 2: *Which decision framework is appropriate to apply within this decision process?*

Sub-question 3: *How does operating leverage influences the systematic risk of the project when switching from outsourcing to internal production?*

Sub-question 4: *Which cost-valuation method is appropriate to apply within this decision process?*

3.2.3 Research motivation

Theoretical motivation
In current literature, no studies are found that address or incorporate the influence of switching between outsourcing and internal production on the systematic risk of a project. This thesis will address this gap by establishing a valuation model incorporating the underlying factors of the systematic risk of a project (i.e. sales volatility, operating/financial leverage) for both free cash flows and net income. Particular focus will be put on the discount rate of the project. It will be investigated which differences arises between net income and free cash flow based valuations and how to interpret them.

Practical motivation
Insource/outsource decisions are often based on solely cost analysis. However, more factors, other than cost, are equal or possibly more important than only these cost factors. Not including the total set of relevant factors may lead to a biased decision advice which, subsequently, results in sub-optimal decision making.

Decision making including all relevant factors is, however, a comprehensive and time-consuming process with many inputs and variables. Firms are often struggling with this fact as they are missing the right knowledge and experience, necessary to construct a comprehensive decision advice. Furthermore, an operational (i.e. easy-to-use) framework is not readily available. This thesis will address this problem by providing a tailored decision advice for the firm.

3.3 Research design

The research is performed using both quantitative and qualitative methods. Quantitative methods are applied when the incorporated factor needs quantitative justification in making a decision. Qualitative insights and discussions serve as input and justification when handling strategic and subjective factors.

3.3.1 Project plan

Contact persons
The thesis is carried out by Berry van Mil, graduating student *MSc Operations Management and Logistics*

at Eindhoven University of Technology. The first academic supervisor is dr. Boray Huang (Eindhoven University of Technology) and the second academic supervisor is dr. Arun Chockalingam (Eindhoven University of Technology). Nick Schillemans, General Manager of Flowserve Roosendaal, and Rob van Pelt, Black Belt, both support the thesis from practical and scientific perspectives.

Project planning

The project starts on August 10th 2018 (week 28) with a duration of 25 weeks (including four weeks holiday). The expected end-date is January 25th 2018 (week 4). The project is divided into four parts: *(1)Exploration, (2)Design, (3)Analysis and (4)Results*. The time schedule is presented in table 2.

Table 2: Time schedule

Process	**Period (2018)**	**Research question**
Exploration	Wk 32-35	
Orientation at Flowserve	Wk 32-34	
Identifying suitable problem	Wk 32-34	
Research proposal	Wk 35	
Design	Wk 36-39	
Literature study: Insource,-outsource decision frameworks	Wk 36-37	SQ1/SQ2
Literature study : Operating leverage and systematic risk	Wk 38-41	SQ3
Analysis	Wk 39-46	
Production	Wk 39-40	
Project valuation	Wk 41-42	SQ4
Supply chain	Wk 43-44	
Support systems	Wk 45-46	
Results	Wk 47-50	
Rating factors and areas	Wk 47	
Scoring and results	Wk 48	
Finalizing / Reporting	Wk 49-50	
Slack	Wk 51-2	

3.3.2 Deliverables

The deliverable of this project is a thesis report including a comprehensive decision advice. This decision advice is further extended with a 'capital appropriation request' (CAR) in case the project leads to a positive advice for insourcing the HVOF process. The CAR is a required document for capital expenditures (CAPEX). It includes request info, justification and a payback time, among others. Furthermore, the company and university are updated on a regular basis for advice and scientific matters.

4 Theoretical background

This section describes the current existing literature towards (1)operating/financial leverage and systematic risk and (2)decision support models. By doing so, an understanding of the current state of these topics is established on which further research can be performed.

First, the relationship between operating leverage and systematic risk is discussed. Afterwards, decision support models are introduced.

4.1 Operating leverage and systematic risk

This chapter will discuss the related literature towards systematic risk and the different kinds of involved leverages within a project. First, operating leverages will be discussed including its relationship with the systematic risk. Second, also financial leverage is discussed as this leverage is in a similar way related to the systematic risk.

4.1.1 Definition

Operating leverage generally refers to the single-period magnification of the uncertainty of operating income (EBIT) relative to the uncertainty of sales (Vanderheiden and A. [1]). One of the reasons why we are interested in operating leverage is because it tells something about the inherent risk of a project/operation, or to be more specific, the standard deviation in returns. For the same reason, financial leverage is being analyzed.

In order to get a broad understanding of operating leverage, literature applies different expressions for this variable. Rubinstein E. [2] defines operating leverage as the difference between unit sales price P_m and unit variable cost V_m (P_m - V_m). Percival [3] explains operating leverage as a reflection of the distribution of total costs within a firm into fixed and variable components. As Brealey [4] states, a business with high fixed costs is said to have high operating leverage. This results in the business being more sensitive to demand changes and, therefore, riskier.

Measuring operating leverage may be defined by profit elasticity functions or accounting variables. In general, earnings before interest and taxes EBIT is considered in these equations:

$$DOL = \frac{\%\Delta EBIT}{\%\Delta sales} \tag{1}$$

Brealey [4] expresses DOL in terms of fixed cost to profits before tax. Note that fixed cost includes depreciation. When omitting depreciation in the fixed cost, the earnings before tax are called EBITA.

$$DOL = 1 + \frac{fixedCosts}{profits} \tag{2}$$

Percival [3] defines DOL further by expressing the equation in terms of quantity sold Q and the break-even point BEP. Instead of an elasticity functions, Percival applied accounting variables:

$$DOL = \frac{Q}{Q - BEP} \tag{3}$$

Furthermore, also Gahlon [5] defines operating leverage in terms of accounting variables. Gahlon defines operating leverage in terms of contribution margin C (unit price P minus unit variable cost V):

$$DOL = \frac{C * E[Q]}{C * E[Q] - F} \tag{4}$$

A prove of the equality between the elasticity and accounting form may be found in appendix A.2.

In order to provide a good understanding of the behaviour of operating leverage, Figure 3 is prepared, showing graphically operating leverage relative to the break-even point. As can be seen, operating leverage increases a-asymptotically towards the break-even point. Therefore, other things being equal, when increasing the fixed cost, operating leverage may increase or decrease depending on the new break-even point. Furthermore, also the contribution margin is partly responsible for shaping the operating leverage curve. A smaller contribution margin results in a less steep DOL curve (see DOL2 in Figure 3), meaning the operation requires a larger demand Q for the same DOL. Note that the setup of this break-even point differs from the general form. Instead of applying a sales line, the contribution margin times Q is plotted. By doing so, one could also visually estimate operating leverage.

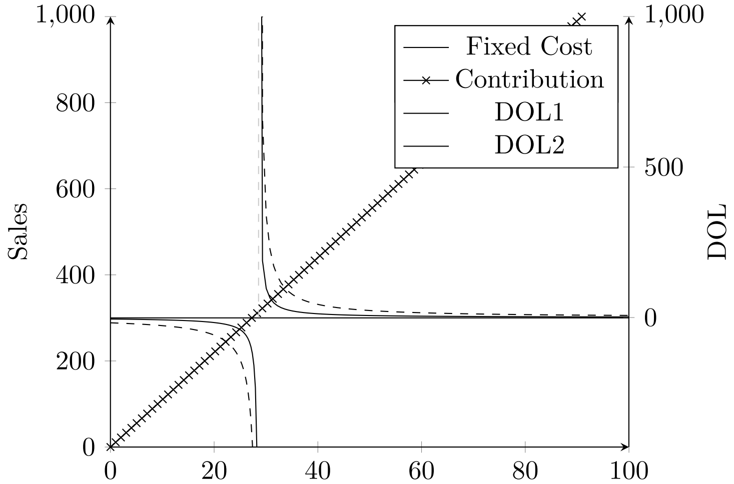

Figure 3: Operating leverage and break-even point

In addition to the definitions above, O'Brien, Vanderheiden (1987) define DOL as the ratio of the percentage deviation of operating income (X_t) from its expectation [E(X_t)] to the percentage deviation of sales revenues (S_t) from its expectation [E(S_t)]:

$$DOL = \frac{\frac{X_t}{[E(X_t)]} - 1}{\frac{S_t}{[E(S_t)]} - 1} \tag{5}$$

O'Brien, Vanderheiden (1987) states that in the special case that when total revenue and total operating cost functions are deterministic, linear, and independent of one another, DOL is constant over all possible values for S_t (i.e the classical model). After some mathematical steps, the same equation as Brealey [4] (Eq.2) is obtained:

$$DOL = 1 + \frac{fixedCost}{E[X_t]} \tag{6}$$

4.1.2 Restrictions

Although operating leverage gives a useful insight into the company's operations, it also has restrictions. First, operating leverage is an ad-hoc measurement. It only considers some variables at the moment of time, ignoring future sales increases, changes in fixed and variable cost, etc. The firm could, for example, change its product mix, the cost of inventory could change and also prices for raw materials are not constant over time. Furthermore, in case of increasing sales in the future, this does not necessarily result in lower operating leverage as also fixed cost could possibly increase due to internal capacity constraints and the need for outsourcing or internally hiring new employees. Secondly, as graphically showed in Figure 3, DOL changes rapidly around the break-even point. Therefore, in case of volatile demand or close to the break-even point, DOL will be limited useful.

4.1.3 Relationship operating leverage and systematic risk

Systematic risk β measures the sensitivity of the returns of a firm relative to market movements. For example, a beta of 1.5 implies that the returns of a firm move 50% more volatile than the market average. More theoretical, systematic risk is denoted as

$$\beta = \frac{Cov(i,m)}{\sigma^2(m)} \tag{7}$$

where:

i = return of the firm
m = return of the market
$\sigma^2(m)$ = variance of the market returns (Constant)

With this formula, market-based betas can be established. However, to estimate the same beta with accounting variables, the covariance has to be further rewritten as

$$Cov(i,m) = \rho(i,m) * \sigma_i * \sigma_m \tag{8}$$

where:

$\rho(i,m)$ = correlation of company's and market returns (Intrinsic, Constant)
σ_i = standard deviation of company returns (Variable)
σ_m = standard deviation of market returns (Constant)

It can be seen that a higher standard deviation of the company returns will directly affect the covariance and, therefore, the systematic risk of the company. Thus, real determinants of systematic risk are variables that influence the standard deviation. In literature, a substantial amount of research is performed to investigate these determinants. Although there is some common agreement regarding the real determinants, it is still not comprehensive. One of the highly likeable determinants of risk that is being investigated is operating leverage. As discussed above, operating leverage refers to the magnification of the uncertainty of operating income relative to the uncertainty of sales.

Besides a large number of empirical studies towards this subject, also some analytic studies are performed. Mandelker and Rhee [6] investigated the effect of operating leverage on risk both analytic and empirical. They present a multiplicative formula to determine systematic risk including DOL and DFL. This outcome of this formula is related to net income.

4.1.4 Financial leverage

Financial leverage is the degree to which a company uses debt during its operations. The more debt the company has more interest has to be paid which reduces the company's profits. The degree of financial leverage (i.e. DFL) is expressed as

$$DFL = \frac{EBIT}{EBIT - I} \tag{9}$$

In the same fashion as the degree of operating leverage, also financial leverage can be written as an elasticity function. This prove may be found in appendix A.1.

4.1.5 Gap

There are two gaps in the literature towards systematic risk and project valuation that will be addressed in this study. First, establishing the project beta for free cash flows, based on different involved leverages is not yet fully established. The equation from Mandelker and Rhee results in a beta for net income only. This formula requires a second term in order to receive a beta for free cash flows due to the involved depreciation. Second, it is not yet investigated which differences arise between a free cash flow valuation and a net income valuation which each its own corresponding discount rate.

4.2 Decision framework

In order to develop a tailored decision model, incorporating relevant elements, a brief literature review towards insourcing/outsourcing decision (i.e. make-or-buy) frameworks is performed. After a short introduction, explaining the definition, risks and benefits and the history, a number of different models are discussed.

The insource-outsource problem is the decision of where to participate and add value in the supply chain. During outsourcing, activities are transferred to third parties. Insourcing is the opposite process of outsourcing, i.e. the process of transferring formerly outsourced activities in-house. Insource-outsource decisions may have major implications for both the strategic and financial objectives of companies. However, as Ford et al. [7] indicated, companies often base there decisions on short term perspectives with cost reduction as primary factor. Supplier factors such as delivery reliability, quality, technical capability and financial stability are often neglected. On the opposite, an increasing recognition of other factors, other than costs, is observed in recent years. Companies distinguish core and non-core processes and are considering more strategy within the insource-outsource decision process.

4.2.1 Benefits and risks

During a insource-outsource decision, the company has to consider both the benefits and risks of the two scenarios. Possible benefits of outsourcing may include: (1)economies of scale of the supplier, (2)reduce demand uncertainty risk, (3)reduce capital investment, (4)increase flexibility and (5)focus on smaller set of tasks. Risks that may arise are: (1)expected benefits are not always realized, (2)costs escalating, (3)dependence on suppliers for service, (4)loss of 'corporate memory', (5)difficult to insource again and (6)unwittingly choosing the same supplier may lead to supplier dominance. Considering all given points, it is clear such a decision requires the fullest attention of management and should not be performed without a firm analysis.

4.2.2 Two main stream approaches

The approaches that support insource-outsource decisions may be categorized into two categories . The first category, and most traditional one (Platts et al. [8]), is mainly focused on costs. Can another company provide the product of process for less money than in-house? One of the first theories based on a cost perspective is the "Transaction cost economics (TCE) theory". This theory not only considers the purchasing price of the product or process, but also other associated costs necessary to obtain the service. Besides the cost aspect, TCE theory partly bases its decision on a combination of 'risk of opportunism' and the level of product/process uncertainty and transaction frequency. Hobbs [9] classified the TCE theory into four key concepts:

- *Bounded rationality.* Rational decisions made by people may be sub-optimal due to limited valuation capabilities.
- *Opportunism.* TCE recognizes that business and individuals will sometimes seek to exploit a situation to their own advantage.
- *Asset specificity.* When partner to and exchange has invested resources to this exchange that have no alternative uses a the partner that has made this investment can be held hostage by the other partner. The investing partner has already paid for the resources, an might be forced to lower the price for example, to get any return to the investment.
- *Informational asymmetry.* As symmetry arises when one party has not shared publicly all information. As a result, transactions are imperfect which may lead to opportunism behavior.

Criticism on the TCE approach is the assumption that people always act with 'guile' and 'opportunism', capabilities pre-exist and transaction costs are well defined and constant.

Later on in history, a substantial amount of other cost-based approaches were developed, giving a sizable repertoire of additional analytic tools aiming to answer make-or-buy decisions on a purely economic level (Platts et al. [8]).

The second stream of approaches are based on a strategic perspective. Taking not only costs into account, but also longer term strategic factors. The importance of incorporating more factors than solely costs has been recognized for many years [8]. As Platts et al. [8] cited Ford and Porter (1915): ".. many other considerations other than price enter the equation...".

A well-known approach is the resource-based view. The resource-based view (Penrose 1959) argues that a firm can be considered as a collection of productive resources on which growth depends on how slack resources are utilized. A firm competitive position depends on its ability to gain and defend advantageous positions concerning these resources. Resources which provide a sustained competitive advantage could be termed as core competences (Prahalad and Hamel, 1990). Key resources are valuable, rare, inimitable or non-substitutable.

The issue with above given approaches and theories is that they are abstract and high-level. Based on simple cost analysis or strategic questions, these approaches advice certain strategies and decisions without paying attention to activities on operational levels and, therefore, lacking an easy-to-use experience. As Platts et al. [8] cited, make-or-buy decisions requires multiple inputs and call for a structured approach. Researches from Cambridge developed a methodical approach which consist of three decisions tools: (1)a technology matrix, (2)a cost model and (3)a strategic framework. Platts et al. [8] further enhanced this process by proposing a framework which integrates all the factors into one model, helping managers with make-or-buy decisions at an operational level. The make-or-buy decision in this framework is a weighted average of ratings across the whole context.

5 Methodology

This chapter describes the framework that will be applied in this study. First, a description of the framework is given, explaining the structure of the overall framework. Second, as part of the framework, this chapter assigns directly the corresponding weight of the project to specific areas/factors for the decision process.

Description decision support model
As the literature on decision models pointed out, it is important to incorporate all factors which have significant value within the decision process (i.e. not solely costs). Furthermore, literature also pointed out that the use of an easy-to-use model is essential within an operational context.

A large number of articles pointed out that one needs to make the distinguishing between core competencies and critical/important competencies that support the core competencies. Based on discussions within the company, the overlay process is not seen as a core competence, but instead, it is considered an important step within the production process for certain mechanical components. Therefore, the decision-model used in this study, which fits the above-given conditions, is the "Multi-attribute decision-making model" (see Figure 9) proposed by Canez et al. [10]. The steps within this model, tailored towards this project, are as followed:

Determine Factors
: The first step in the decision process is to determine which factors are important towards the decision. This process consists of discussions with stakeholders and close involved individuals in order to rank and weigh all the areas and factors as indicated in the model.

Rating Capabilities
: The second step is rating both in-house and outsource company capabilities. In proportion with the level of importance of the concerning factor, the factor is in-depth analyzed for both the outsourcing company and future in-house capability. These analysis and discussions are converted to ratings with the use of tailored proformas. The proformas are formed based on discussions with management.

Cost Valuation
: Thirdly, a cost valuation is exercised in order to measure the financial attractiveness and feasibility.

Conclusion and Results
: The final step in the process is determining the scores for both outsource and in-house capabilities and make the comparison. This naturally leads to the decision advice for the HVOF-process. A sensitivity analysis is applied, ensuring robust decision advice and a good understanding of critical factors. A qualitative discussion with stakeholders regarding the results is arranged for the final advisory.

In order to structure the decision model on an operational level, the framework separates the decision in four areas, namely (1) technology and manufacturing processes, (2) cost, (3) supply chain management and logistics, and (4) support systems. Subsequently, each area consists of a number of factors on which the capabilities are rated and compared.

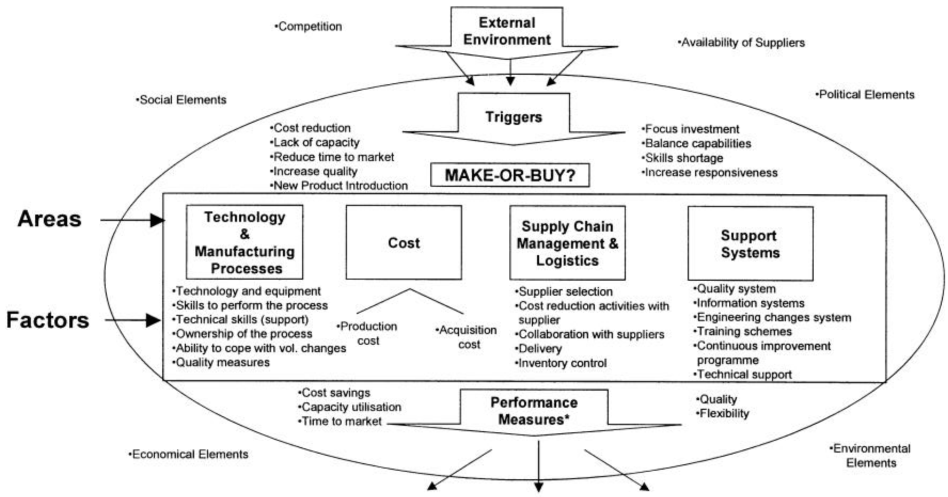

Figure 4: Decision framework (Canez, Platts, Probert (2000))

In the remainder of this chapter, the areas and factors are ranked according to their importance. The next four chapters will discuss each area separately, in which the factors are rated for both in-house and outsourcing capabilities.

Weightings

Assigning weights to the areas and factors, relevant to the decision, is an important step in the process. Factors that are considered as important are in this way correct valued when comparing scores between in-house and outsourcing capabilities. Weights are determined during a multi-disciplinary team meeting (manufacturing, quality assurance/control, finance, purchase, planning). First, the areas will be discussed and second, the corresponding factors are reviewed and weighted.

Assigning the correct amount of weight to each of the four different areas dependent on (1) the objectives of the project and (2) on the dependability of the process in certain areas. For example, when insourcing a new project, it is key to consider the feasibility of the project in terms of production, as there would be no current knowledge about the production process).

Table 3: Distribution area weighing

Area	Description	Ranking	Weight
1	Technology and manufacturing processes	1	25
2	Supply chain management and logistics	1	25
3	Costing	1	25
4	Support Systems	1	25

Based on the multidisciplinary team meeting, production and support systems were pointed out as the most important areas to consider regarding the feasibility of the project. Supply chain/logistics and costs were considered as the most important areas regarding the objectives of the project. Based on these conclusions, all four areas were assigned the same amount of weight (see Table 3).

The next step is to assign the correct amount of weight to each different factor. This is performed in the same fashion as with the areas. In the table below (Table 4), an overview of the factors with their corresponding weights is provided. During the multi-disciplinary session, attendants have discussed and voted for different factors. Thereafter, the factors were sorted on the level of importance and converted to weights. This conversion is performed using the same method as seen in the paper of Platts et al. [8].

Table 4: Distribution Factor weighing

Factor	Description	Ranking	Weight
Technology and manufacturing processes			
1	Availability of skilled employees	1	52
2	Machinery/equipment	2	27
3	Technical support	3	15
4	Handling volume changes (flexibility)	4	6
Supply chain management and logistics			
1	Lead time	1	52
2	On-time delivery performance	2	27
3	Material flow performance	3	15
4	Information system (i.e. process control)	4	6
Cost			
1	NPV-analysis	1	100
Support Systems			
1	Corporate requirements (e.g. certification)	1	52
2	Quality control	2	27
3	Training	3	15
4	CIP	4	6

Technology and manufacturing processes
First, as obtaining skilled operators for other production processes is already an issue on a regular basis, it is expected it will be no exception for this production process. Furthermore, it is also known that at current outsource companies these problems exist. Second, machinery/equipment is considered as an important factor as it would be a new production process with limited current knowledge. It is key to investigate this area thoroughly in order to establish a reliable production process.

Supply chain management and logistics
Within supply chain and logistics, lead-time is considered as the most important factor as one of the objectives of the project is to reduce this lead time. Both the length and on-time performance of the lead time are directly noticeable by the customer and, therefore, need to be guaranteed by the new production process.

Cost
Regarding the cost area, a net present value (NPV) analysis is established. Within this analysis the effects of degree of operating leverage (DOL) is incorporated, demonstrating the effect of DOl on the

systematic risk during in-house and outsource production. Furthermore, the effects on systematic risk between applying EBIT based cash-flows and 'earnings after interest and taxes' based cash flows are demonstrated.

Support Systems
Quality is one of the most important requirements for Flowserve's end customers. Therefore, a thorough investigation of applicable corporate requirements and quality control steps is necessary to perform.

6 Analysis

6.1 HVOF process

In this section, the HVOF process is being analyzed. First, a description of the process itself is given. Second, the applied materials are discussed. Thirdly, the process steps are discussed and lastly, the quantities are being analyzed.

6.1.1 Description

High-velocity Oxygen Fuel (HVOF) is a common overlay method with a chemical heat source. The method is designed to carry out gas combustion where it can apply coating material in the form of accelerated molten particles with high kinetic energy. As a result, a dense overlay is built that forms a strong bond with the substrate. This process is the most common method for applying all carbide-based materials.

6.1.2 Materials

The coating materials used for HVOF spraying contains 73%-88% tungsten carbide and are available in various metallurgies for different applications. Regarding Flowserve, the two most common coatings in this group are Flowserve RAM21 (86% WC) and Flowserve RAM25 (73% WC). Both metallurgies produce coatings with high wear resistance, RAM25 being superior in corrosion resistance and high-temperature applications. Besides the tungsten carbide coatings above also Colmonoy coatings can be applied with HVOF. The most common Colmonoy coating within Flowserve is Colmonoy #6 which is a nickel-based alloy with Chromium Boride.

6.1.3 Production Steps

In the table below (Table 5), a complete overview of the process is pictured-out. Besides the description, both the run time and set-up time are given. These process times takes into account an average bath size of two units.

Table 5: HVOF process

Step	Description	Run time [min]	Set-up time [min]
1	Masking grit blasting	10	
2	Grit blasting	5	
3	Cleaning	5	
4	Hard masking HVOF	5	
5	Pre-heating	5	
6	Apply coating	5	15
7	Grinding	60	30
8	Inspection	5	

Preparation (Step 1-5)

All surfaces to be coated are required to be grit blasted prior to the coating process. For this reason, surfaces that need to be protected against grit blasting are covered with electrical tape, thermal putty or Teflon gaskets. After grit blasting, the mask is removed and the grit blasted surface is cleaned thoroughly with ethanol alcohol. The next step is adding a second mask. This mask is identical to the previous one and consist of electrical tape or thermal putty. After masking, the surface is being pre-heated. The next phase is the actual process of applying the overlay.

HVOF Procedure (Step 6)

The HVOF procedure consists of the set-up of the system and applying of the actual overlay. For now, the assumption is that the system includes a robot for automatic usage. Then, the first step is to set-up proper work holding of the product and 'hard-masking'. Hard-masking is a carbon steel plate which acts as main protection for over spraying. The mask added during preparation acts as fine-protecting the remaining overspray.

After proper work holding and masking, the next step is programming the robotic arm. The robotic arm is 'taught' to follow a path along the surface and some remaining parameters are inserted. The last step during the set-up of the system is 'arming' the spray booth. All systems are verified to be ready for operation and the doors of the cabin are locked.

Now that the set-up is completed, the actual application of the coating can be performed. The desired number of preheating and coating passes are entered and the coating can start. During the coating process, the operator is responsible for maintaining the right temperature. After the application of the coating, the surface cooled and cleaned. The last step is to grind the surface to the required specifications.

Grinding (Step 7)

In order to finish the sleeve after the overlay is applied, the sleeve needs to be grinded. Grinding is performed until the required surface specifications are met. Some parts do not require grinding. In those cases, the overlay that is added to the part is precisely on diameter. This is seen at so-called 'specialities' within the pump division. Grinding is performed by the same outsource company as the one who applies the coating. Regarding pumps, this could be a mix of external and internal grinding.

6.1.4 Quantities

The total number of overlays is distributed over three areas: (1)Seals, (2)Seals QRC, (3)PMC and (4)PMC QRC.

Seals
There are approximately 23 different tungsten carbide (TC) based coatings and ten Colmonoy coatings. In the figure below (Figure 5) an overview of the 16 most common coatings is given. The numbers are an average of the period 2012-2017. As can be seen, the largest share of these coatings is ZA-typed (Tungsten Carbide). Tungsten carbide and Colmonoy #6 coatings are accounting for the largest share of applied coatings.

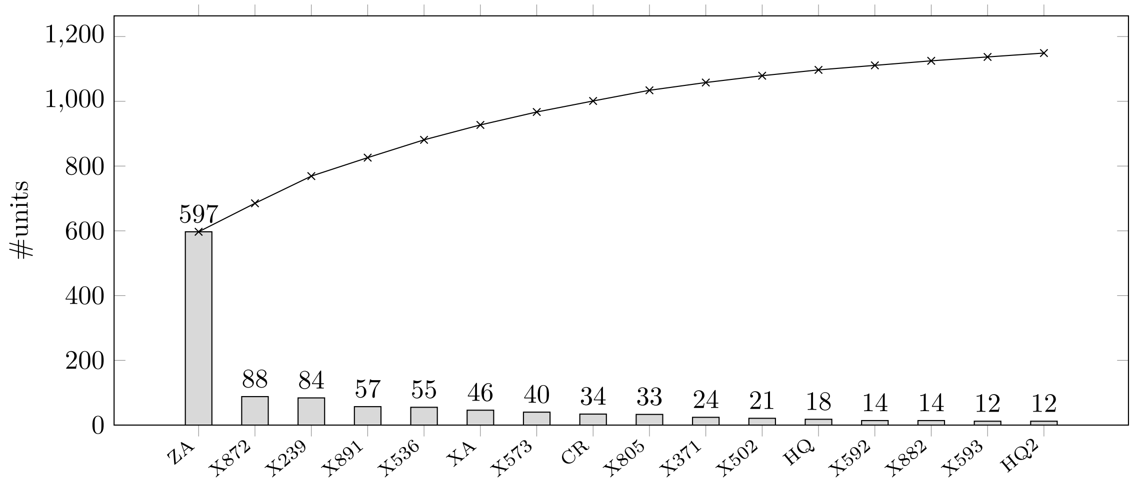

Figure 5: Overlay type distribution (average 2012-2017)

The average total number of outsourced coatings is pictured out in figure 6. As can be seen, the number of outsourced coatings has first increased and then stabilized. Over the past four years, the number of outsourced overlays was approximately 1350. The engineering department expects that for the upcoming years the number of these overlays will remain stable with a standard deviation of approximately 10%. The average purchase value of the past four years (2015-2018) was approximately €210,000.

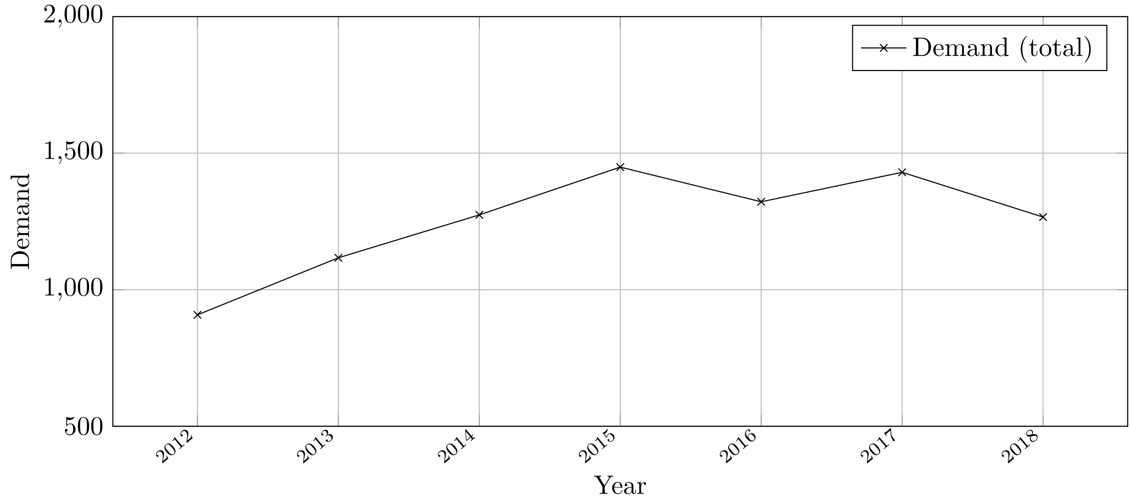

Figure 6: Overlay demand (2018 forecasted)(σ=10%),

Regarding the outsource companies there are mainly three companies responsible for the overlay process. Two of these three companies are located in the Netherlands. The latter is another Flowserve company located in Olomouc, Czech Republic. In the figure below (Figure 7), the number of overlays outsourced to the three companies is pictured out. Due to risk management, the amount of outsourced overlays is approximately equally distributed among the two dutch outsource companies.

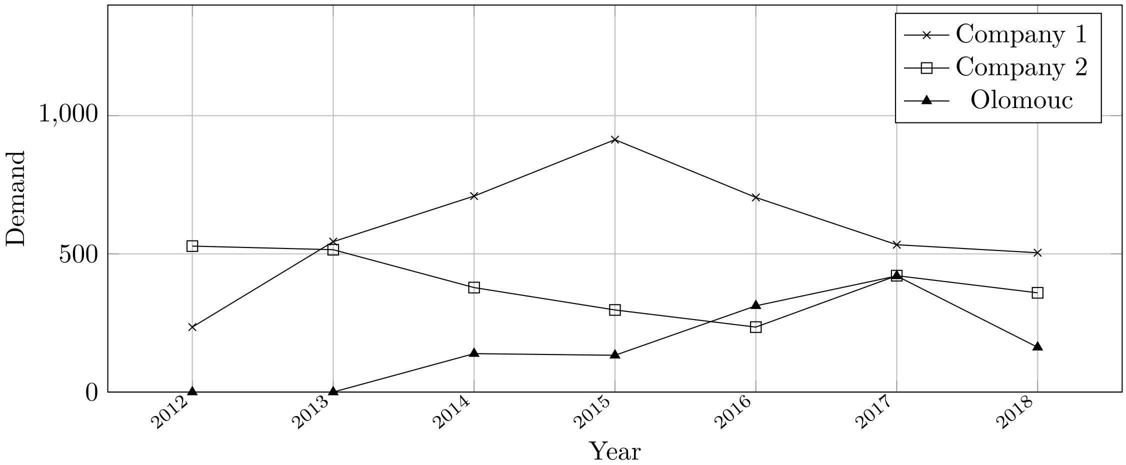

Figure 7: Outsourcing among company 1 and 2 and Olomouc (2018 forecasted)

Besides the outsourced overlays, Flowserve also applies Colmonoy overlays internally. The current process of adding these Colmonoy #6 overlays is manual and the equipment used for these overlays requires to be updated. A new HVOF-system would make this current system unnecessary. The number of internally applied Colmonoy overlays is approximately 350 (averaged over the past three years). In the figure below (Figure 8), the number of Colmonoy overlays per type is pictured out.

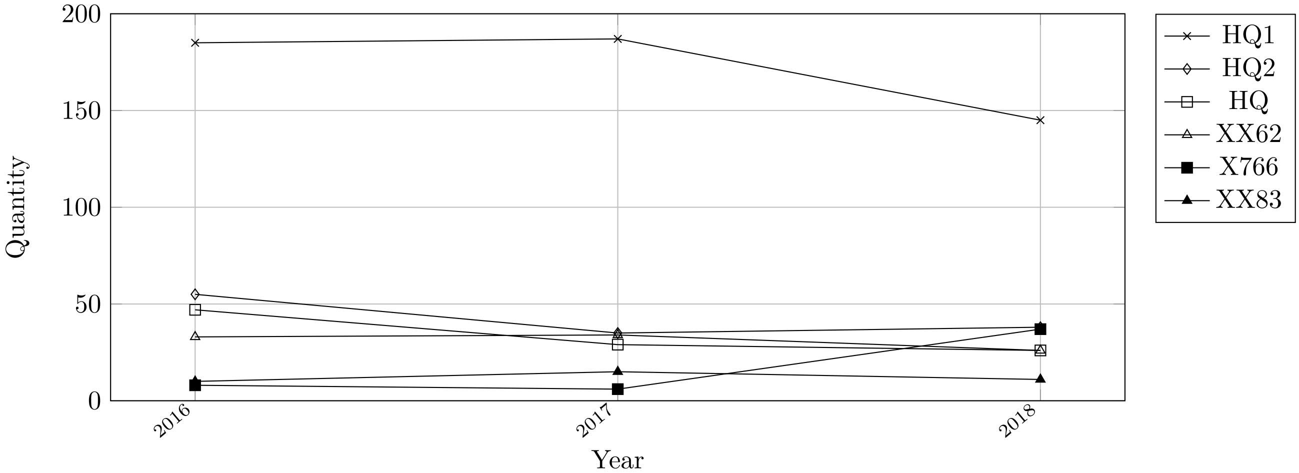

Figure 8: Colmonoy overlays (2018 forecasted)

Seals QRC

The quantity of overlays at the Seals QRC is approximately 70 per year. The Seals QRC applies standard RAM25 overlays to worn out parts regardless of the current type over overlay.

PMC

For the PMC the demand of 2017 and 2018 is considered. Due to the large variation in part size at the

PMC, only parts that could fit into the HVOF-cabin are considered. The approximate number of units that could qualify for an internal HVOF process is 107 per year. The purchasing cost of these overlays is €107,000 with an average unit price of €997.

Pump QRC
For the number of overlays at repair, the years 2017 and partly 2018 are considered. In 2017 and 2018, 169 and 231 overlays were outsourced. After forecasting the remaining months of 2018, an average of 240 overlays per year is obtained.

Overview quantity of overlays
In the table below (Table 6) an overview of all types of considered overlays is given.

Table 6: Demand NPV (2018 forecasted)

Devision	Demand	Note
Seals HUB	1367	Average 2015-2018
QRC Seals	70	2017
PMC	107	Average 2017-2018
QRC Pumps (Repair)	239	Average 2017-2018
Total	**1843**	

6.2 Cost valuation

This section discusses and performs the valuation of the financial side of both the internal production and outsourcing project. First, the methodology will be discussed. Second, the required parameters are reviewed and to conclude the results are extensively analyzed and interpreted.

6.2.1 Methodology and parameters

The valuation model applied in this study is based on a certainty equivalent version of the CAPM (Armitage [11]). As the normal CAPM formula requires asset returns based on the market value of the asset, this would lead to a circularity problem when valuing the project.

To compare two different projects (i.e. in-house and outsourcing), the valuation model is being established twice and compared which each other.

In the following steps, the methodology is being further described. First, the structure of the two different cash flows (i.e. free cash flows and net income) are described. Second, the certainty-equivalent CAPM method is discussed and lastly, the two net present value analysis itself are established.

Free cash flows and net income
For each project, a net present value will be calculated for both its free cash flows and net income. Net income may also be described as the profit after tax and is commonly used in accounting. Free cash flow, on the other hand, is the actual cash flow produced by the project. This cash flow is obtained by adding back the depreciation which was earlier subtracted for the net income.

In table 7, a more in-depth structure regarding the cash flows are given.

Table 7: NPV structure for time t

	Metric
1	Sales_t
2	Fixed operating cost_t
3	Variable operating cost_t
4	EBITA_t (1-2-3)
5	Depreciation_t
6	EBIT_t (4-5)
7	Interest
8	EBT_t (6-7)
9	Tax_t
10	Profit after tax_t (7-8)
11	Free cash flow (10+5)

Certainty-equivalents
When applying the standard CAPM equation, the obtained cost of capital is used to discount future cash flows for time and risk simultaneously. The certainty-equivalent version breaks this down into two steps. First, the certainty-equivalent cash flow of the expected cash flow in the future is calculated. During this step, only discounting for risk is performed. Second, the obtained certainty-equivalent cash flow is discounted for time to obtain the present value.

The certainty-equivalent value of a cash flow T dates ahead is

$$CE(Y_{jT}) = E_0(Y_{jT})(1 - \lambda\sigma^*_{jM})^T \tag{10}$$

where

$CE(Y_{jT})$ = certainty-equivalent for cash flow at time t
Y_{jt} = cash flow of project j at time t
$E_0(Y_{jT})$ = expected cash flow of project j at time t

Lambda λ denotes the market price per unit of covariance risk, $[\text{E}(\text{R}_M)\text{- R}_F]/\text{var}(\text{R}_M)$. The covariance of the projects are fixed but adjusted to the standard deviation of the cash flows for every time period T. Sigma* σ^*_{jM} is then denoted as the covariance between cash flow and market returns divided by the expected cash flow. The covariance between cash flow and market return can be written as

$$cov(Y_{jT}; R_{MT}) = \frac{1}{(p-v)(1-T)} cov(Q_{jT}; R_{MT}) \tag{11}$$

Note that this covariance is the same for both free cash flows and net income as the only difference is a constant (i.e. depreciation) that is being added.

The correlation coefficient between sales Q and market returns R_{MT} is assumed to be equal to the correlation coefficient of the firm's sales with the market returns. To obtain this correlation coefficient the equation for beta is applied and re-arranged

$$\beta_i = \frac{\rho(i, M) * \sigma_i * \sigma_M}{\sigma^2(M)} \tag{12}$$

re-arranging gives

$$\rho(i, M) = \frac{\beta_i * \sigma^2(M)}{\sigma_i * \sigma_M} \tag{13}$$

To show that the correlation coefficient for sales Q is equal to the correlation coefficient of the cash flows Y_{jT} the formula for this correlation coefficient term is written as

$$cor(X;Y) = \frac{cov(X;Y)}{\sigma(X) * \sigma(Y)} = \frac{cor(X;Y) * \sigma(X) * \sigma(Y)}{\sigma(X) * \sigma(Y)} \tag{14}$$

As cov(X;Y) can be written as cor(X;Y)*σ(X)*σ(Y), it can be seen that applying different standard deviations does not influence the correlation coefficient as they are cancelled out.

Finally, the corresponding cost of capital of the project is

$$R_j = \frac{1 + R_F}{1 - \lambda\sigma^*_{jM}} - 1 \tag{15}$$

Net present value
Now that the certainty-equivalent cash flows can be determined, the remaining step is to discount these cash flows for time. The obtained present values are then applied within the net present value analysis. The net present value analysis for free cash flow will consider both future cash flows as also the initial investment. Regarding net income, only the present values of future net incomes are considered as the initial investment will be incorporated by way of depreciation. The two NPV equations for free cash flows and net income are then denoted as

$$NPV_{FCF} = -I_0 + \sum_{t=1}^{10} \frac{CEQ_{jt}}{(1 + r_F)^t} \tag{16}$$

and

$$NPV_{NI} = \sum_{t=1}^{10} \frac{CEQ_{jt}}{(1 + r_F)^t} \tag{17}$$

Then, instead of solely considering the production step which could be outsourced or performed internally, the total production line is considered. This production line is categorized in three stations: (1)part manufacturing, (2)HVOF applying and (3)assembly and quality control. In the figure below (Figure 9), this production line, including the option to insource or outsource, is visually presented.

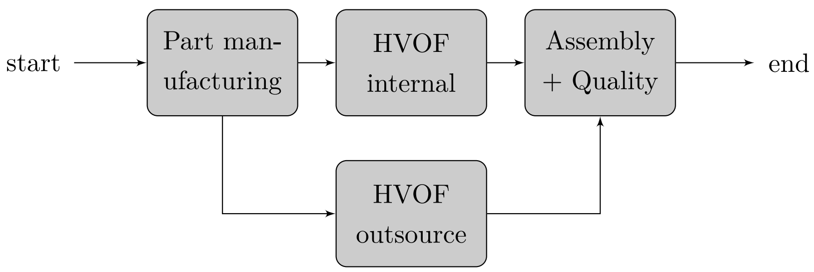

Figure 9: Flowchart production process

By considering the total production line instead of solely considering the HVOF process, more stable results are obtained as possible high fluctuations in one step are flattened out by other steps. Furthermore, it makes sense to consider the total production flow of the parts because eventually, it is the total production line which is responsible for the performance towards customers.

Degree of operating, financial and depreciation leverage
By applying a valuation method based on certainty-equivalent cash flows, it is not required to make adjustments between the two projects based on their DOL's and/or DFL's. These effects are directly incorporated in the risk discounting step. However, the valuation method gives useful insights into how DOL/DFL influences the systematic risk of the two projects.

In literature, it is already known that when applying net incomes the project beta may also be obtained by the following equation (Mandelker and Rhee [6])

$$\beta = DOL * DFL * \beta_{sales} \tag{18}$$

In this model, DOL and DFL are calculated with accounting variables instead of elasticity functions. Prove of this equality may be found in the appendix (see appendix A.1 and A.2). Then the corresponding equations for both DOL and DFL are respectively

$$DFL = \frac{EBIT}{EBIT - I} \tag{19}$$

and

$$DOL = \frac{(p-v)Q}{(p-v)Q - F} \tag{20}$$

Regarding free cash flows, the beta equation including DOL and DFL (eq. 18) could be supplemented with the leverage effect of depreciation which is added back to the net income to obtain the free cash flows. This is performed in the same fashion as the degree of operating and financial leverage. The complemented beta equation for free cash flows is

$$\beta = DOL * DFL * DDL * \beta_{sales} \tag{21}$$

where DDL stands for the degree of depreciation leverage and is calculated as followed

$$DDL = \frac{netIncome}{netIncome + depreciation} \tag{22}$$

Note that in contrast to the formulas for DOL and DFL, depreciation is added instead of subtracted due to its positive effect on the standard deviation of these free cash flows.

Variable cost station 2 (HVOF)
Internal production
Average 2017 purchase prices for HVOF overlays at outsourcing company 1 and 2 are €172 and €153, respectively. Compared with the price lists of these two companies, the average sleeve diameter is 2.5-3.5inches. This sleeve dimension is also in line with experiences of employees that work regularly with these sleeves. Subsequently, a cost calculator for a JP-5000 coating system (developed by Flowserve

Kalamazoo) is used to determine the approximate HVOF cost per unit. A sleeve with a dimension of 2.5-3.5x8inch results in a variable cost of €47-66. Besides material cost, also spare parts and grinding cost are included. Spare-part cost is approximately €6 per part (Kalamazoo calculator) and grinding cost are approximately €10 per hour.

Regarding the internal production cost for pump parts, the assumption is that these parts experience approximately the same savings as observed with seals parts (i.e. PMC: 20% and Pumps QRC: 64%). In addition, the pump parts chosen for the internal HVOF process are on average larger than the seal parts but still small enough to use in the HVOF and grind-blasting cabins. In terms of material price which accounts for the largest share of the variable cost, the assumption is that these pump parts requires three times more material than the seal parts. The internal for these pump parts is then set to €226. The total average internal cost price amounts then to €110 for both seals and pump parts (See Table 8).

Outsource price
The average price for outsourced HVOF overlays over the past four years was €175 (€207 for Olomouc and €169 for the two external outsource companies) (appendix A.5, A.6 and A.10). These prices showed a fairly constant level (appendix A.6). For the QRC an average purchase value of €371 was observed. Regarding the pumps division, the average purchase price experienced by the PMC was €996 and for repair €381. The total average purchase price for all locations together is then €259. This purchase price is without transportation and order placement cost. Order placement cost is +10%. For transportation estimates see appendix A.9. To conclude, the total outsources price per unit is €301. See Table 8 for more data.

Important to note is that the two outsource companies have communicated they want to increase prices. Till now Flowserve has refused to agree with these increases due to low on-time performance of companies.

Table 8: Variable cost internal/outsourcing

		Cost	
Devision	Type	Internal	Outsource
Seals HUB	Material	€47-66	
	Spare-parts	€6	
	Grinding	€10	
	Total	**€82**	**€209**
Seals QRC	Material	€47-66	
	Spare-parts	€6	
	Grinding	€10	
	Total	**€82**	**€422**
PMC	Material	€200	
	Spare-parts	€6	
	Grinding	€10	
	Total	**€226**	**€433**
Pumps QRC	Material	€200	
	Spare-parts	€6	
	Grinding	€20	
	Total	**€226**	**€1110**
	Average	**€110**	**€299**

Capital investment, depreciation period, salvage value

As indicated in section 'technology and manufacturing process', the estimated capital investment, based on a quote is €440.000. This quote is based on a full system. However, within Flowserve, there is already an un-used robotic arm present (excluding drivers) that could possibly be used for this project's purpose. Therefore, the actual investment would be approximately €350.000. The depreciation period for machines is 10 years and the expected salvage value is approximate €100.000. This salvage value is assumed to be risk-free and, therefore, only needs be discounted for time.

Risk-free rate, market-interest rate, inflation

The applied risk-free interest rate is 0.5% (10-years dutch obligation) and the market risk is 7,2% (Dow Jones historical average). The applied inflation rate is 2% (approximate average past 30 years).

Overview parameters

The table below (Table 9) presents an overview of all parameters applied in the model.

Table 9: Overview parameters

	Metric	Note
Beta Flowserve		
Market beta	1.55	Yahoo finance (3-years monthly)
Correlation Market		
St.dev. Flowserve	7.26	Appendix A.3
St.dev. Market (Dow Jones)	2.93	Appendix A.4
Variance Market (Dow Jones)	8.61	Appendix A.4
Correlation FLS - Market	0.63	Eq. 13
Capital investment (internal)	€300,000	
Depreciation (10 years)	€30,000	
Interest	n/a	
Risk free interest rate	0.5%	10-years Dutch obligation
Market interest rate	7.2%	Dow Jones historical average
Inflation rate	2.0%	
Tax rate	20%	
Project variables		
Demand	1843	constant
Unit sales price	€600	Approximation
Station 1 variable cost	€30	Approximation
Station 1 fixed cost	€150,000	Approximation
Station 2 (internal) variable cost	€100	Yearly increase of +2%
Station 2 (internal) fixed cost	€200,000	
Station 2 (outsource) variable cost	€300	Yearly increase of +2% + year 1 initial increase of +10%
Station 2 (outsource) fixed cost	€1500	
Station 3 variable cost	€2,50	Approximation
Station 3 fixed cost	€12.500	Approximation

6.2.2 Results

In this section, the results from the net present value analysis are discussed. First, the two projects (i.e. internal production and outsourcing) are discussed in isolation of each other, going more in-depth in the differences between net income and free cash flows. Second, the comparison between the two projects is established. Again, the difference between a net income and free cash flows based valuation is analyzed. To conclude, for both projects their leverage parameters, discount rates and betas are discussed. The results of the valuation are included in appendix A.13.

NPV Internal production
Between the net present values based on net income and free cash flow for internal production, there is a small difference in favour of the net income based valuation. One of the differences between the net income and the free cash flow based valuation is the way in which depreciation/investment is being handled. During free cash flow valuation, the investment is being subtracted immediately at time zero. Therefore, this amount of money is not discounted for time. During the net income valuation, the same investment is equally spread over the upcoming years in the form of depreciation, resulting in a lower present value of cost due to time discounting.

The net present value based on net income is €1,722,545 (€1,673,432 + €49,113 (PV(salvage value)) and for free cash flow this value amounts to €1,635,323 (€1,586,210 + €49,113). The salvage value is earlier assumed to be risk-free and therefore, only needs to discount for time. In terms of the applied discount rate, the net income based valuation has an average discount rate of 16% and the free cash flow on maintains an average discount rate of 15%. In figure 11, the present values for each period are pictured out.

NPV - Outsourcing
Between the two net present values for outsourcing, there is no difference. This is because there is no depreciation involved during outsourcing. Net incomes and free cash flows are for that reason equal. The net present value based on net income and free cash flows is €1,143,596. The average discount rate for both net income and free cash flow based valuation is 14%. In the figure below, 11, the course of the present values for outsourcing are visualized.

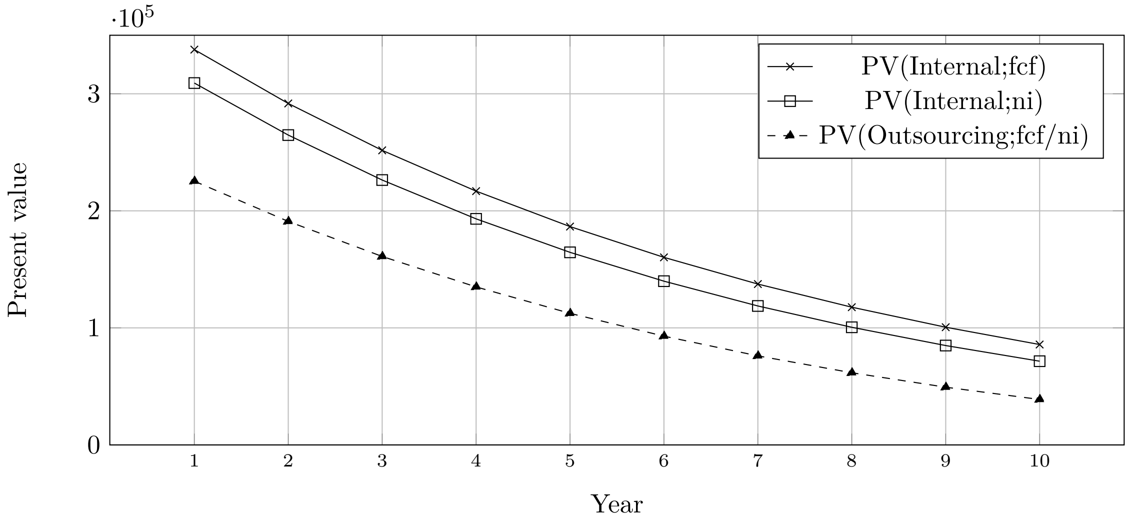

Figure 10: Free cash flow and net income based present values for in-house and outsourcing

Internal production vs. outsourcing

When making up the comparison between internal production and outsourcing the net present values are in favour of internal production although outsourcing is subjected to a lower discount rate. It could, therefore, be interesting to investigate which amount of savings are required for equal net present values between internal production and outsourcing. Furthermore, also the corresponding discount rates could be analyzed. This analysis is performed by making the "variable internal production cost" variable while other parameters remain constant. This step is performed twice for both the net income and free cash flow based net present values.

The minimum amount of required savings for equal net income NPV's in terms of free cash flow is €39,965 for the first year. The corresponding variable cost is, in this case, €203 (€171 for HVOF step). The corresponding average discount rates for free cash flows is 16%.
Then, the same step is performed for the free cash flow based net present values. The minimum amount of required savings is, also in terms of free cash flows, €54,755 for the first year. The corresponding variable cost is €194 (€161 for HVOF step). The average discount rate for free cash flows is 16% and 16% respectively.

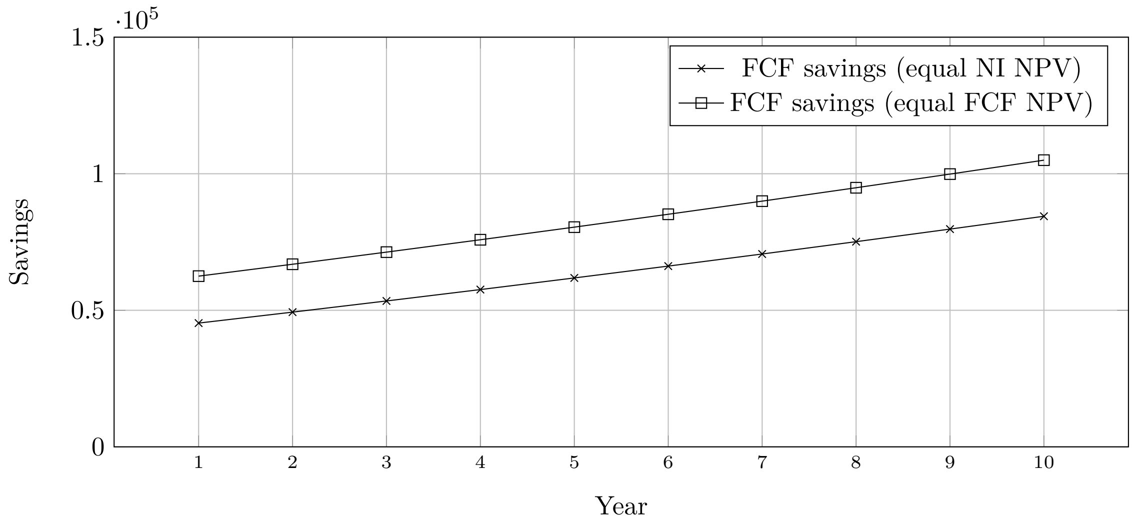

Figure 11: Free cash flow and net income based present values for in-house and outsourcing

Degree of operating and financial leverage

The degree of operating and financial leverage is the same for both net income and free cash flow based valuations and are presented in the figure below (Figure 12). Note that the degree of financial leverage is being omitted due to full equity funding in both projects. Therefore, this leverage is constant with a value of 1 during the entire time horizon of both projects.

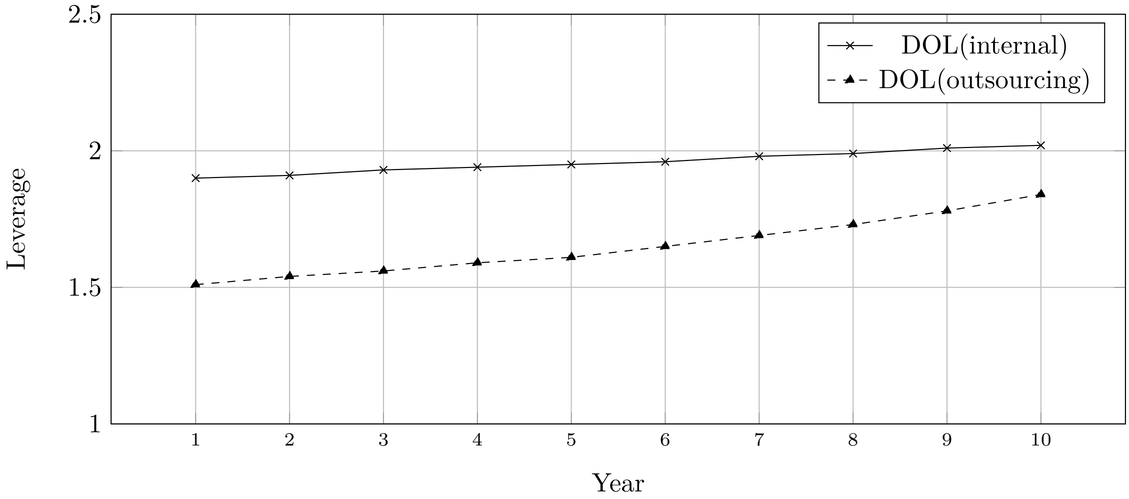

Figure 12: Degree of operating leverage

As can be seen in Figure 12, the degree of operating leverages raises during the lifetime of the two projects although the fixed cost is being held constant during that time. This happens because for both the two projects the variable cost expected to increase every year with a certain percentage. For that reason, the contribution margin (selling price minus variable cost) decreases. As a result, the fixed cost is becoming relative larger every year which increases the degree of operating leverage. Note that the DOL for outsourcing increases more rapidly than internal production. This is explained by the initial higher variable cost which is subjected to the yearly increase.

Degree of depreciation leverage
The degree of depreciation leverage only applies to the free cash flows of a project with the presence of depreciation. Therefore, it only applies to internal production. As can be seen in Figure 13, the degree of depreciation leverage decreases over time, which is negative for the free cash flow as this means that the positive effect of depreciation on the risk of these free cash flows decreases. This can be explained by the depreciation which is constant over time but, at the same time, a decreasing net income due to increased variable cost.

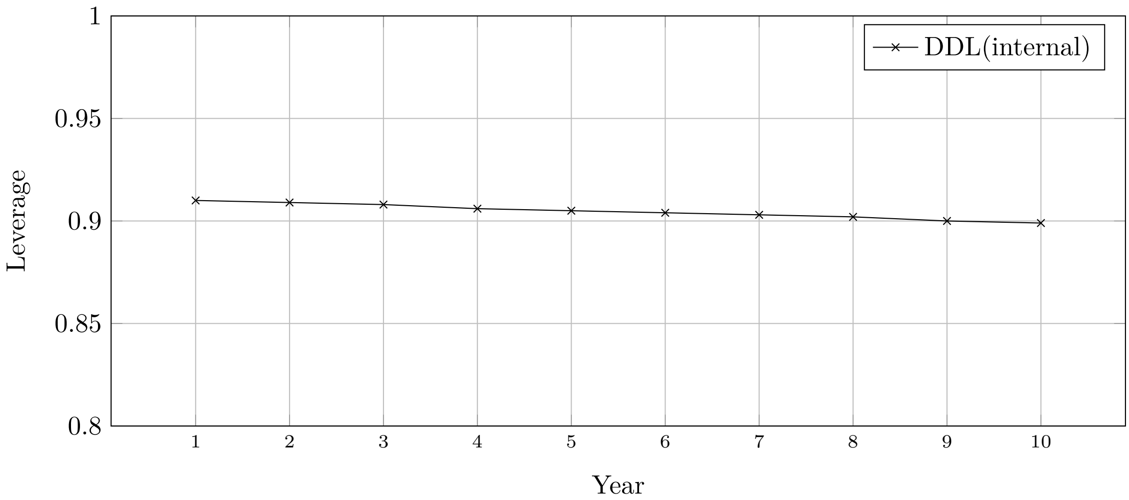

Figure 13: Degree of depreciation leverage during internal production

Beta (Systematic risk)

As earlier presented during the results, the discount rate for internal production is higher compared to outsourcing. This difference in terms of net income was larger than in terms of free cash flows. However, the difference in risk may also be shown in terms of beta. The beta for both net income and free cash flows based valuation may be calculated directly for each year using the following formula

$$\beta_{ni} = \frac{cov(ni; R_M)/E[ni]}{\sigma^2(M)} = \frac{\sigma^*_{jM}(ni)}{\sigma^2(M)} \tag{23}$$

and

$$\beta_{fcf} = \frac{cov(fcf; R_M)/E[fcf]}{\sigma^2(M)} = \frac{\sigma^*_{jM}(fcf)}{\sigma^2(M)} \tag{24}$$

or indirectly using the formula from Mandelker and Rhee [6] for net income and the same adjusted formula, including the degree of depreciation leverage, for free cash flows

$$\beta_{ni} = DOL * DFL * \beta_{sales} \tag{25}$$

and

$$\beta_{fcf} = DOL * DFL * DDL * \beta_{sales} \tag{26}$$

Because the last two, decomposed beta, equations give more insight into how beta is structured, these equations are used for further analysis.

First of all, β_{sales} is equal for both internal production and outsourcing as both projects are based on the same input (demand) with certain volatility. Furthermore, they both share the correlation with the market and use the same market parameters in their equations. Thus, in this case, for both projects the sales betas β_{sales} are 2.15. From this point, the actual project beta of the two projects changes in different ways. After multiplying the sales beta with DOL, DFL and, for free cash flows only, DDL, the project beta's are obtained for both internal production and outsourcing and pictured out in the figure below (Figure 14).

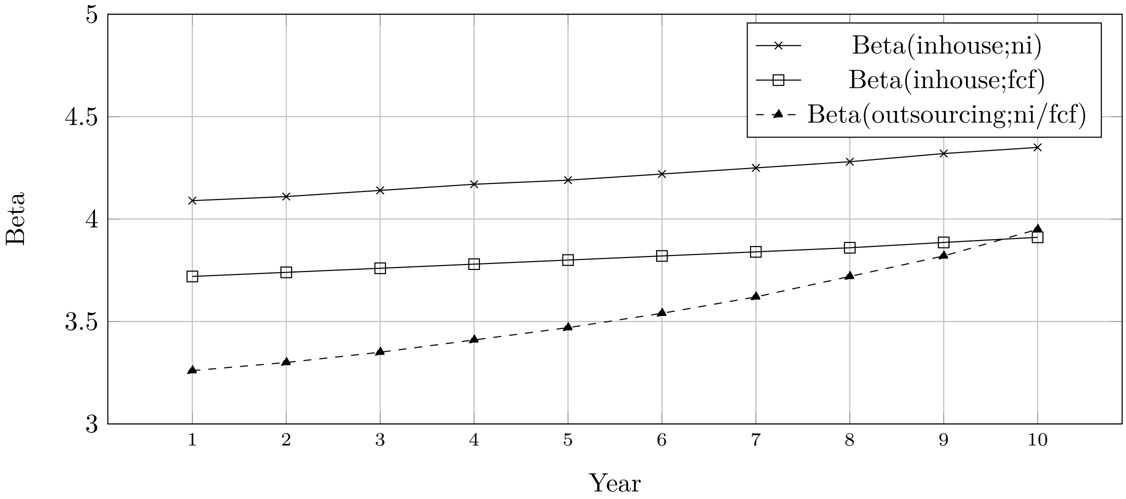

Figure 14: Project beta's (Internal production and outsourcing)

As can be seen in Figure 14, the initial project beta for outsourcing (equal for net income and free cash flow due to no depreciation) start lowest. However, as the project develops overtime this beta increases significantly more than the project beta during internal production. This can be explained by the variable cost of the two projects. As the variable cost of the outsource project increases more rapidly due to a higher initial starting cost, also the degree of operating leverage during outsourcing increases at a higher pace. Therefore, it can be seen that a given moment the project beta of outsourcing is getting even larger than the project beta during internal production based on the free cash flows.

Payback period (CAPEX requirement)
One of the criteria within a CAPEX request is the payback period which requires to be as low as possible. Preferably lower than five years. Considering the net income savings of the three four years (€101,478, €107,230, €113,098) and the initial investment of €300,00, the pay period amounts to 2,8 years which is within the required payback period.

6.3 Technology and Manufacturing Process

This section discussed the four considered factors for the area technology and manufacturing processes: (1)availability of workforce, (2)required equipment and technology, (3)technical support and (4)coping demand changes.

6.3.1 Availability of Workforce

As the HVOF process requires specialized operators to operate the system, it is key to be able to hire sufficient skilled operators in a timely manner. As earlier pictured out (Table 5), there are several steps that need to be accommodated under the operator. Considering these steps, the operators could be categorized into (1)HVOF operators and (2)grinding cell operators.

HVOF operators
Operators for the HVOF system requires training. Training of two weeks was required at a different Flowserve location in America for the robotic arm. During this training, the operators were trained to

teach the robotic arm so it can handle the HVOF spray gun along the right path when adding the overlay. Furthermore, when purchasing the system, training is supplied by the supplier to teach the operators the system itself.

The overall process of applying the coating is considered as not too difficult. This is mainly due to the use of the robotic system which automates the most difficult steps during the process. Masking of the products is seen as the most challenging part. Furthermore, due to the wearing of spare parts (e.g. HVOF torches etc.), the process of applying the coating is not completely constant. This problem requires the operators to get a feeling of the process and interim measurements should be performed to ensure proper overlays.

Grinding
Grinding is common practice at Flowserve. The department of human resources indicates that recruiting new operators for this process is no issue when timely communicated (three months in front). This is especially the case when Flowserve is able to offer a contract for a longer period of time. This situation does not hold in case more operators are required within a short period of time. In that case, this problem is reduced as much as possible with employment agencies. Grinding basis material (material of which the parts are made from) or HVOF overlays does not change the kind of operator. Solely the tooling is adjusted.

6.3.2 Technology and Equipment

Equipment
Based on the production process as explained in table 5, the following equipment is required: (1)Grit blaster, (2)Cleaning facility, (3)HVOF system, and (4)grinding cell.

Grit blaster
Currently, there is a grit blaster present at Flowserve that is being used by the QRC seals division for repair activities. According to engineering standard D4-5, the grit blasting shall be carried out with #16 alumina grit. Furthermore, the blasted surface finish should be between 3.8 and 6.4 micrometres (150 and 250 microinches) RMS.

Cleaning facility
Grit blasted parts must be cleaned with ethanol alcohol. Therefore, a small cleaning facility is required. While performing this step, gloves must be worn to protect against contamination.

HVOF system
Regarding the actual HVOF system, Flowserve has two options: (1)adding the coatings manually or (2)adding the coatings automatically. Both systems have their benefits and disadvantages. As HVOF spraying is a hazardous process, Flowserve has determined to only consider a robotic system due to safety concerns. The following table (Table 10) provides an overview of the required equipment.

Table 10: HVOF system set-up

			Required?	
Step	List	Cost	Manual	Automatic
1	Thermal spray enclosure	€23.472	Yes	Yes
2	Dust collector	€67.161	Yes	Yes
3	Robot arm	€80.000	No	Yes
4	Robot safety system	€28.000	No	Yes
5	Turn table	€27.300	No	Yes
6	HVOF system	€177.500	Yes	Yes
7	Operator/maintenance training	€8.500	Yes	Yes
8	On-site supervision of installation	€24.500	Yes	Yes
	Total price system		€276.633	€436.433

As can be seen, there is a considerable price difference between the two options. This is due to robotic equipment that is required or omitted when choosing one of the two options. The robotic version has several benefits relative to the manual version. The robotic version is less sensitive for human mistakes, more accurate, and programs can be saved so that set-up times can be further reduced. The prices above are derived from a quotation for a completely new set-up. However, there is already a robotic arm present within Flowserve that is currently not being used. The use of this robot would reduce the investment cost by saving on a new robotic arm. The additional cost of an internal CE approval needs to be considered in case the secondhand robotic arm is used.

The thermal spray enclosure is required to reduce the noise produced by the thermal spray process which can generate noise levels nearing 135 dB. The enclosure is designed to reduce the high noise levels to an acceptable 85 dB. Furthermore, all thermal spray processes generate dust. A properly sized dust control system is required for collection of this over-sprayed material. The size of the enclosure is 365 x 305 x 274 cm and the doors are 208 x 213 cm.

In order to turn the product during the spray process, the system is provided with a turntable. This turntable has a load capacity of 500 kg and has a diameter of 600 mm. The turntable has a rotating speed range of 0 - 450 RPM and is able to manual tilt with a range of 0 - 90 degrees.

To conclude, also the kind of materials that will be applied are important to consider. As different materials require different kits, it is important to know which materials Flowserve requires to apply. As earlier discussed in this study, the three most common materials to consider are two tungsten based materials (RAM21 and RAM25) and Colmonoy #6. Working with kits instead of manually cleaning the system during each switch between a different material reduces set-up time and increases quality. As the above-mentioned materials are most common for overlays, these three materials are incorporated in this research. However, at a later stage, it could be investigated if it is interesting to add more different materials to such an HVOF-system.

Lastly, the delivery time is approximately 16 - 20 weeks after acceptance of the order.

Grinding cell

The last step in the process is finishing of the coatings. According to engineering standard D4-5, components can be left 'as sprayed', polished or ground to obtain the required finish. Generally, wear surfaces and components with critical dimensions are ground finished. Surface finish is generally between 0.4

and 0.6 µm (16 and 24 µ-in) RMS. Critical components within the hydraulic passages (impeller vanes, volute lips etc.) can be polished using a diamond grinder (wet) to decrease potential surface friction and maximize pump efficiency.

A suitable grinding cell for HVOF overlays is the Studer grinding cell. As Flowserve has already this type of grinding cell, it is favourable to also use this grinding cell for the HVOF coatings. Therefore, the current utilization rate of the Studer was analyzed. For this, the period January 2017 until June 2018 was considered (Appendix A.7).

The average utilization of the Studer is 6.3 hours. Therefore, the Studer is available for at least two additional shifts. This implies the availability of 4160 hours per year (2*8*5*52) for the sleeves that are provided with an HVOF overlay. Furthermore, besides the Studer, there are more grinding cells available at the PMC. There are different grinding cells for inside and outside diameters as also for sides of parts. Besides manual grinding cells, there is also a CNC grinding cell available in case required. The capacity of the grinding cells at the PMC is not fully utilized yet, enabling the possibility to also use these cells for the coatings.

Lastly, it is important to have the right tooling for grinding HVOF overlays. As the PMC already grind HVOF overlays for pump parts, the required tooling is already available (e.g. clamping, grinding stones, etc.).

Workforce requirements

In order to determine the required workforce, simple calculations are performed to determines the service level and utilization rate for each particular process step according to an assigned FTE level. In the table below (Table 11), the corresponding required workforce is pictured out. The applied time per unit incorporates an average batch size of two (see appendix **??**). The process is divided into preparing + coating and grinding.

Table 11: Required workforce

Process step	Time/unit [min]	Workforce [FTE]	Utilization [%]
Preparing + Coating	42.5	0.7	88
Grinding	75	1.3	83

Working environment / safety / permits

Environmental permits

Regarding environmental permits, there are now issues expected. There are already similar activities performed within Flowserve that also did not require any additional permits.

Emission / dust

During the spray process, the air becomes contaminated and needs to be filtered. Therefore, the HVOF system is provided with a dust collector. The location of the dust collector depends on the thermal spray process that will be used and the materials sprayed. Generally, the filters are placed outside the facility due to health and safety issues.

Storage / working stock

Applying HVOF overlays requires kerosene, nitrogen and liquid oxygen. All three are dangerous substances which require the fullest attention and safety measurements. Within the PMC, there is another process which applies flame spraying. This process requires comparable substances which are also subjected to safety rules. Substances that are not used at the moment of flame spraying are stored outside the building. Also, the working stock is kept to a certain limit. The HVOF process would require similar treatment.

Table 12: Storage dangerous substances

Substance	Storage
Kerosene	
Nitrogen	Storage in dry, cool and ventilated area (preferable outside/corrosion free area for containers)
Liquid oxygen	

CE-marking
CE marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area (EEA). When purchasing the total system at 1 supplier, the supplier can declare the CE-marking. Otherwise, when the firm decides to purchase subsystems at different suppliers, the firm has to self-certify the total system.

Employee safety
When investing in the HVOF process, one has the choice for manual or automatic coating. Regardless of the associated cost, which is pictures in table 10, Flowserve will choose for the automatic set-up due to quality and speed considerations. Therefore, when applying the coating, the operator will be completely shielded toward all hazardousness activities during the process (e.g. sound levels, contaminated air, etc.).

Location
As there is sufficient available space for a system such as for HVOF, it is expected there will be no issues finding a suitable location. One particular location which seems suitable is a spacious cabin which is used for a different overlay process. This cabin could be divided into two separated cabins. As this cabin is not soundproof nor equipped with the required ventilation for HVOF coating, a new soundproof cabin and ventilation cannot be omitted.

6.3.3 Technical Support

High running time is essential for a successful operation. Downtime results in higher cost and/or unsatisfied customers. Units need to be outsourced to other suppliers with higher cost and/or longer lead times. Therefore, being able to fall back on an excellent technical service during a breakdown is key for operations.

There are several suppliers active in Europe which all offers a portfolio of support activities: fast field service support, technical phone support, remote diagnostics, preventative maintenance programs, system calibration, service agreements, etc. Therefore, it is expected that the arrangement for technical support will not be an issue.

6.3.4 Coping demand changes

There is always some variation in demand. This variation can either be predicted or non-predicted (i.e. unforeseen demand). A production process needs to be able to cope with this variation in the most cost-effective way as possible. Furthermore, regardless of the level of demand, it is favourable to maintain stable and low lead times as much as possible. From an operational perspective this implies the need for a responsive (planning) system, sufficient skilled resources, etc.

Considering the demand data over the past seven years (Figure 6 and appendix A.5), it can be seen that the variation of the experienced demand is relatively low. The standard deviation over the last three years was approximately 6%, resulting in a controllable system. Note that this is regarding the demand observed in the seal's division. Demand at the pump division (both PMC and repair) are showing more variation in demand. Being a controllable system is positive for both outsourcing and internal production. Furthermore, due to a possible bull-whip effect, it is expected that the variation at the outsource supplier will be higher compared to internal production. This may lead to more production/planning problems at the outsource company while it would be less when performing the process internally.

To conclude, as manual HVOF coating is highly dependent on available and skilled operators, periods of higher demand also need to be covered by the same limited number of operators. Currently, the number of operators at the outsource companies is low (e.g. Outsource company 1 has only two qualified operators). In contrast to this manual process, an automatic process enables the possibility to not necessarily require the same skilled people. Therefore, periods of higher demand could possibly be better processed by other, similar operators. The HVOF system itself will unlikely to be the bottleneck itself due to its short processing time. The main bottleneck would be the preparation phase and the grinding step.

6.4 Supply Chain Management and Logistics

This section discusses the four considered factors for the area supply chain management and logistics: (1)lead time, (2)on-time performance, (3)material flow and (4)control system.

6.4.1 Lead Time

First, the total production lead-time of parts including an overlay, as experienced by the customer, is analyzed. Hereby, a distinction is made between parts intended for original equipment assemblies (OE), after-market (AM) assemblies, and aftermarket parts going directly to the customer. More specifically, an analysis towards this distribution showed that 49% of the parts were intended for AM assemblies, 18% for AM spare parts and the remaining 33% for OE assemblies (see appendix A.8.

Because a considerable share is going directly to the customer as single spare-part (18%), two tables for both outsourcing and in-housing are prepared, showing the corresponding lead-times for assemblies and single spare-parts. In the next part, first the lead-times during outsourcing are analyzed and second, the in-house lead-times are analyzed. Lastly, a brief comparison is made to conclude.

Lead time during outsourcing
In the following two tables (Table 13 and 14), the lead time during outsourcing for both single spare-parts and assemblies are pictured out:

Table 13: Single part lead time - Outsourcing

Step	Process	Lead-time [working days]
1	Order processing & confirmation	1
2	Part (sleeve) production	3
3	Transport to outsource location	1
4	Overlay Production	8
5	Transport to Flowserve	1
6	Inbound	2
7	Outbound	1
8	Transport (Europe)	1
Total		18

Table 14: Assembly lead time - outsourcing

Step	Process	Lead-time
1	Order processing & confirmation	1
2	Wait for release discrete job (DJ)	max(0; $LT_{max} - LT_{sleeve}$)
3	Part (sleeve) production	3
4	Transport to outsource location	1
5	Overlay Production	8
6	Transport to Flowserve	1
7	Inbound	2
8	Stock into inventory (WH)	max(0; MAX_{delay})
9	Assembly	1
10	Outbound	1
11	Transport (Europe)	1
Total		>19

As can be seen in both tables 13 and 14, differences in lead-time between the two possible situations arise during steps 2, 8 and 9 of the assembly timeline. The lead time during step 2 of an assembly dependent on the lead times of all other parts, required for the assembly. In case a different part, other than a sleeve, has a longer lead time, the sleeve has to wait a certain amount of time before the MRP system releases the sleeve. The second difference arises at the end of the production timeline (step 9). Because an assembly can only start when all parts are on-hand, the start of the actual assembly dependent on the latest arrived part. Lastly, due to the assembly step itself, 1 extra day is required in case of an assembly.

The average lead time of the outsource step depends mainly on three outsource companies. One inter-company located in Olomouc, Czech Republic and two external outsourcing companies located in The Netherlands. Dependent on the required delivery speed, sleeves with ample allowed lead time are outsourced towards Olomouc, remaining sleeves with tighter lead times are outsources to one of the two external outsource companies in the Netherlands.

In the tables above (Table 13 and 14) a lead time of 8 workings days is involved for the outsource step. This number is established by considering the average lead times over the past six years. In the table below (Table 15) the average lead times per year are pictured out. For 2018 approximately 6 six months of data is used.

Table 15: Lead time outsource step (in working days)

	2012	2013	2014	2015	2016	2017	2018
Outsource company 1	9.7	7.1	8.3	7	7.6	8	7.9
Outsource company 2	9.6	9.3	9.9	8	6.6	8.4	10.1
Olomouc (inter-company)					*42.2	*38.6	*32.7

**Production orders outsourced towards Olomouc includes the production of the sleeve itself. Furthermore, adding HVOF overlays is relatively new for Olomouc. A great amount of improvement has been observed over the last three years. Moreover, Olomouc is outsourcing the overlays to a local third party.*

As can be seen in table 15, the lead time of the two outsource companies located in The Netherlands was on average 8 working days. Therefore, the total average lead time for a single spare-part is approximately 18 working days. When considering the total lead time of an assembly, the lead time of a single spare-part can be considered as the under-bound for an assembly. Therefore, the lead time of an assembly including an overlay will always be larger than 19 days. The added lead time during an assembly depends on other required parts of the assembly.

Lead time during internal production

In the case of in-housing the process, the outsourcing step is replaced by the required production steps. These include (1)applying overlay/coating and (2)grinding. Furthermore, the transportation and inbound steps can be omitted. Then, the following two tables (16 and 17) are established for in-house lead times:

Table 16: Single part lead time - Internal

Step	Process	Lead-time [days]
1	Order processing & confirmation	1
2	Sleeve production	3
3	Applying HVOF overlay	1
4	Grinding	1
5	Quality inspection	1
6	Outbound	1
7	Transport (Europe)	1
	Total	9

Table 17: Assembly lead time - Internal

Step	Process	Lead-time [days]
1	Order processing & confirmation	1
2	Wait for release discrete job (DJ)	max(0; $LT_{max} - LT_{sleeve}$)
3	Sleeve production	3
4	Applying HVOF overlay	1
5	Grinding	1
6	Quality inspection	1
7	Stock into inventory (WH)	max(0; MAX_{delay})
8	Assembly	1
9	Outbound	1
10	Transport (Europe)	1
	Total	>10

As can be seen in table 16 and 17, the average lead-time for a single spare part during in-house production is nine working days. The minimum lead-time for an assembly is is ten working days. To conclude, the difference in lead-time between the two scenarios is considerable. By insourcing the process, a lead-time reduction of approximately ten working days is expected. This will have an instantaneously positive effect on the 18% single spare-parts that are going directly to the customer after production. Regarding the other 82% intended for assemblies, the effect of this reduction is less observable due to other involved parts but it enables the possibility to shorten lead-time for also these assemblies. Moreover, AM assemblies often require short customer lead times, benefiting more from such a reduction in supplier lead time.

6.4.2 On-time performance

On-time delivery performance (OTP) measures the level of being able to meet predetermined dates on which delivery is expected. This measure can be divided into (1)meeting the request date and (2)meeting the promise date. The former one is specified by Flowserve and it indicates the date on which Flowserve requires the order. The promise date is the date on which the outsource company promise to deliver the outsourced part. Both dates are important measures to consider and are telling something different regarding the delivery performance.

Request and promise date
First, a high level of being able to meet the request date implies flexibility and responsiveness. Second, being able to meet the promise date on a high level implies reliability. In this case, the supplier is able to deliver as upon agreed on which decreases lead time risk. However, during analysis towards the promise date, it is observed that not every data point (i.e. production order) is provided with a (correct) promise date. In contrast to the request date, which is automatically updated by the system, the promise date is manually added and, therefore, subjected to human mistakes.

Supply chain risk
Besides the actual on-time performance, also supply chain risk needs to be considered. With supply chain risk, possible disruptions such as broken-down machines, loss of operators, scarcity in materials, etc are considered. These disruptions, when happening, may result in major disruptions towards Flowserve and their customers. For both internal and outsourcing risk is discussed briefly for a general impression.

Outsource company
After performing the analysis, average OTP results of 63%, 68% and 99% are obtained for outsourcing company 1, 2 and Olomouc respectively (see appendix A.12). The performance of the two outsource companies are considerably lower than the average supplier performance. In contrast to this lower performance, Olomouc has a high-performance rate. This can be explained by the longer allowed lead time they have. The reason for the lower outsource performance is less obvious and possibly has several causes. First of all, during a visit at one of the two companies, it was noticed that the way of working was less structured and professional (e.g. operators that are searching for equipment,etc.), resulting in loss of time. Also, the outsourcing company is not always fully prepared for every part that needs to be provided with a coating. Some parts require equipment that deviates from the standard, resulting in additional required production time. Besides possible causes at the outsourcing company, there is also the potential for improvement at Flowserve itself. Currently, an outsource order to one of the two outsourcing companies is send 'after' the part that needs to be outsourced is manufactured. This manufacturing step in the process takes on average 3-4 working days. By changing this communication process (i.e. communication towards outsource companies before the part is manufactured) the outsource companies are 3-4 days earlier informed, enabling possible required preparation steps. Analysis of the OTP of the outsource suppliers also showed that a large share of the orders that were late was late with just one day. It is not precisely clear to which extent earlier communication will increase OTP, however, an increase itself would be quite obvious. For especially this last reason, the OTP of the two outsources companies need to be interpreted carefully.

Internal production OTP
As the HVOF coating process would be new for Flowserve, there are obviously no historical data available. Instead, it would be reasonable to assume that this new process will follow the average OTP of other items scheduled for internal production. Therefore, the OTP request of 'aftermarket make-to-order parts' is assumed. This OTP is on average 88%.

Implications for OTP towards customer
Besides the OTP of Flowserve suppliers, also the OTP of Flowserve towards their customers is of importance. Therefore, the total amount of shipped orders over the past two years are analyzed. Because it not possible to filter out all orders including a coating (e.g. assemblies, etc.), only orders consisting of single parts (AM) with a coating are considered.

First, the OTP of all orders is determined. Over the past two years, 233.012 orders were shipped. 17,215 of these orders were over-due, resulting in an OTP of 93%. Then, all single part orders including a coating are filtered out. This results in a number of 406 shipped orders of which 82 orders were over-due. The corresponding OTP is 80%. Note that the 93% not only includes single part orders but also assemblies, resulting in higher risk being over-due.

To conclude, there is a considerable difference in OTP between solely after-market orders including a coating and the average OTP of the total amount of shipped orders. As the average internal OTP of after-market make-to-orders parts is 88%, an OTP improvement of approximately max 8% (taking into account possible improvements in communication between Flowserve and outsource companies) for approximately 18% of the total amount of orders including a coating is expected. Regarding the other part of coatings (aftermarket assembly and OE assembly), an explicit improvement in OTP is hard to establish due to several other factors that could possibly result in over-due orders. However, it is obvious that also for that this part improvement will be noticeable, especially for AM assemblies which often requires short customer lead-times.

6.4.3 Material Flow (Inventory management)

Discussion/comparison to which extend both the in-house and outsource scenarios can maintain sufficient inventory (i.e. able to obtain the right (approved) materials necessary for production).

Required materials
Required materials for overlays consist mainly of the two types of powders and fuel for the system. Powders that are recorded on the GMS approved supplier list (e.g. RAM21, RAM25) are already evaluated and approved to meet the established GMS Standards and, therefore, readily available for purchasing. In case a new not yet evaluated and approved overlay/coating material is considered, an additional review on the physical properties should be conducted.

Furthermore, there are parts subjected to wearing which need to be replaced after a certain amount of production time. All parts listed are readily available on the market (e.g. through the supplier of the HVOF system etc.). As grinding is already common practice at Flowserve, the required grinding stones are also readily available.

Table 18: Required material list

Process	Material	Life-time [h]
HVOF	Wc86-Co10Cr4 (Tungsten Carbide powder RAM21)	n/a
	Wc73-Cr20Ni7 (Tungsten Carbide powder RAM25)	n/a
	Water	n/a
	Oxygen	n/a
	Kerosene	n/a
	Nitrogen	n/a
	Coaxial Stabilizer	200
	Combustion chamber	200
	Inter connector	200
	6" Barrels (∼10 hr/ea.)	10
	Power feed tubes (∼50 hr/ea.)x2	50
	Miscellaneous parts (tubing, hoses,check valves, etc.)	100
Grid Blasting	#16 aluminum grit	n/a
Grinding	Different grades of grinding stones	n/a

As all required materials are readily available, the expectation is there will be no difference in terms of inventory management. Both the current outsource companies and Flowserve should be able to obtain the materials without any issues. Considering the history of the outsourcing companies, scarcity of material can happen incidentally. However, due to the number of different available suppliers risks like this can be diversified easily.

6.4.4 Information/Control system

Outsourcing and in-house production both require different information control systems. In the case of outsourcing, two or more different firms need to align their businesses as good as possible. Due to different cultures, habits and other practical issues, outsourcing requires additional communication streams and extra attention in order to work properly and reduce uncertainties. A number of issues experienced are non-confirmed orders (is being improved since last year), miscommunication among agreed lead times (including or excluding transport time unclear), quality standards, unclarity about which persons are responsible for contact, etc.

It is expected that issues, as given above, will reduce as the relationship between the two firms becomes more mature. However, due to the earth of these relationships, extra attention and clear communication remain required and possibly other issues in the future cannot be excluded.

In the case of in-house production, the expectation is that communication will be more clear and direct. Problems during production are directly communicated or visible for any person of interest which enables responsive measurements.

6.5 Support Systems

6.5.1 Corporate requirements and quality requirements

It is important for any overlay material approved to meet a specific overlay GMS Standard and/or specific material code to provide consistent performance capabilities no matter which approved material is applied. It is also important for any supplier approved to apply an overlay material to do so consistently and according to established requirements, no matter which supplier is requested to apply the overlay/coating material.

Flowserve has defined three categories for overlay materials which require different evaluations:

Category 1: An existing overlay material grade that has been evaluated and approved to meet an established GMS Standard and applicable material codes and has been recorded on the overlay GMS approved supplier list for product use.

Category 2: A new not yet evaluated and approved overlay material grade targeted to meet an established GMS Standard where it is similar to but may or may not be exactly the same as existing approved material grades to which it is targeted to be approved as an equivalent.

Category 3: A speciality, design, or customer specific overlay material grade not supported by an established GMS Standard and targeted for limited use where the grade of overlay material must be the defined material with no equivalent or substitution allowed.

Furthermore, also the suppliers of the overlay/coating can be classified into one of the five primary conditions defined below:

Condition 1: An existing supplier where the overlay material grade itself has been approved to meet an established GMS Standard (Category 1) and the supplier has been approved to apply this material grade to Flowserve parts.

Condition 2: An existing supplier where the overlay material grade itself has been approved to meet an established GMS Standard (Category 1) but the supplier has not yet been approved to apply this material grade to Flowserve parts.

Condition 3: An existing supplier where the overlay material itself is new and has not yet been approved to meet an established GMS Standard (Category 2) but has been proposed as an equivalent to an approved material grade for application to Flowserve parts.

Condition 4: A new supplier where the overlay material grade proposed for application to Flowserve parts has been approved to meet an established GMS Standard (Category 1) or is new and has not yet been approved to meet an established GMS Standard (Category 2).

Condition 5: A new or existing supplier where a speciality, design, or customer specific overlay material not supported by an established GMS Standard (Category 3) is required.

Evaluation process

Dependent on the applicable material category and supplier conditions above, a pre-selection of required qualification levels is determined. As these qualification levels increases in complexity and cost, it is important to maintain the same sequence as indicated.

Regarding the material categories, when purchasing an already evaluated and approved material grade, category one is applicable. In case a new not yet approved, but similar material grade is proposed, material category two is applicable.

Dependent on the material category, supplier condition two or three are applicable. Condition two in case an already approved material grade is used and condition three in case a new proposed material grade is being used.

Qualification levels:

Level 1: Commercial review (applicable)
Review of commercial pertinence. Determine whether pertinent criteria such as cost, delivery lead times, part size capabilities, etc. fall within a defined need and can provide acceptable results.

Level 2: Data sheet material properties review (applicable in case of material category two)
This level of review shall evaluate the physical properties (chemical composition, mechanical properties, thermal properties, and application process) of a potential overlay material grade. Any category 1 material grade being evaluated to qualify a new supplier should not need this level of review since the material should have been evaluated for physical property compliance in its original approval process.

Level 3: Supplier quality system review (not applicable)
This level of review shall audit the quality system and production processes for any supplier targeted for overlay material application approval. The audit will determine whether the supplier has adequate in-house systems and processes established and functioning to satisfy Flowserve Quality Assurance acceptance criteria or these are deficiencies that must be addressed before Flowserve can consider doing business with the supplier.

For a Condition 1, Condition 2, or Condition 3 supplier situation, a quality system approval as applicable to overlay material suppliers should have already been established by Quality Assurance based on a previous quality system review and periodic update review where required. In such cases, this level of review can be waived and considered completed.

Level 4: Overlay application & structure review (applicable)
This level of review shall evaluate representative parts to audit the supplier's application capabilities to meet Flowserve design criteria and audit specific structural characteristics versus the overlay supplier's data sheet properties and any applicable Flowserve overlay GMS Standard requirements.

A minimum of three parts (4R10406 sleeve) must be provided by the supplier. This audit shall be performed by appropriate Engineering associates and the results shall be compared to the application criteria specified in the 1T-8157 document, the material properties specified on the manufacturer's data sheet, and any applicable overlay/coating GMS Standard. The audit includes different inspections and laboratory measurements and are listed below:

1. Visual inspection of each as determined part to determine whether any unacceptable surface characteristics or defects are present. The overlay color and consistency should be noted versus expectations and/or typical criteria for the overlay type.
2. Laboratory measurement of the overlay surface finish of each as received part. According to criteria for the 4R10406 design and the 1T-8157 document, this surface finish should be 16 RMS or better unless specified otherwise.
3. Laboratory measurement of each part's overlay area hardness. Many of the overlay types specify hardness according to the HRC (Hardness Rockwell C) and/or HR15N (Hardness Rockwell 15N) measurement systems. Each part's overlay area should first be tested using the HR15N test at five random locations. To determine the accuracy of the HR15N measurement obtained and ensure that any affects from the substrate material hardness are eliminated, Knoop 500 (500 gram load) hardness tests should also be conducted at five random locations.
4. Laboratory review of metallographically prepared samples of each as received part for the thickness of the as applied overlay and the substrate material, and estimated porosity. This level also includes a destructive wear test (according to ASTM G65) and destructive bond test (according to ASTM C633-79)

Evaluation and implementation documentation
Each overlay material and/or overlay supplier evaluation shall be documented by preparing an evaluation report presenting the target parameters and the results obtained. This report should present the information necessary to support either approval or disapproval of the overlay material and/or overlay supplier attempting to become qualified. The report should be sent to Flowserve Engineering FFD located in Kalamazoo, Michigan for evaluation and approval. Approval or disapproval is given within 4-6 weeks.

Bi-annual qualification tests
A bi-annual test should be performed to ensure the required level of quality. This process is identical to level four of the qualification process. Liquid penetrant testing of overlaid surfaces is to be performed only if requested by the customer.

6.5.2 Quality performance

In terms of quality, it is expected that internal production will lead to quality improvement. First of all, considering the machinery of the two outsourcing suppliers, both outsourcing companies applies overlays with the use of a robotic arm. In that perspective, no improvements would be established when performing the process internally apart from having a newer system.

The current quality performance of both outsourcing suppliers is approximately 98%. This is a reasonably good performance although the average of all suppliers is higher. More interesting would be the fact that not all deficiencies from the outsource companies are reported. As every deficiency would require to be reported in a so-called NCMR (Non-Conforming Material Report), smaller deficiencies are often not reported due to time constraints. From all parts that are received back from outsource company 2, approximately 25% requires re-work (stated by quality control). Regarding outsourcing company 1 this is considerably lower. The actual quality performance would, for this reason, be lower than the 98% observed by the system.

6.5.3 Training

When purchasing an HVOF-system from a supplier, an operators and maintenance orientation training is supplied. Furthermore, operators at a different Flowserve location in the USA have followed a training of two weeks in order to operate the system. This training was mainly oriented towards the programming and use of the robot so that the arm can follow a path along the part, enabling the spray gun to apply the coating. When the project is getting more crystallized, support from Flowserve Kalamazoo is readily available.

6.5.4 CIP

CIP (continuous improvement program) is common practice within Flowserve as it is a large company with many different improvement programs all the time. Therefore, there is a great number of skilled people (Black belt, green belt, etc.) suitable for optimizing project such as the HVOF overlay/coating process. This is also seen at Flowserve Kalamazoo. Flowserve Kalamazoo invested three years ago in a similar HVOF project. Since then, they made large improvements in different steps throughout the whole process. Flowserve Etten-Leur can apply this knowledge and experience directly to his project and make improvements steps from there.

In contrast to Flowserve's position, the two outsource locations are considerably smaller, implying less availability to people able to optimize the process. It is therefore expected that such a project will improve at a faster pace than at other outsourcing companies.

7 Results

This section discussed the results of the study. First, the score is being analyzed and checked on robustness by way of a GAP and sensitivity analysis. Second, the decision advice for management is presented.

7.1 Score

After performing a comprehensive analysis towards the four areas manufacturing, supply chain, cost and quality, all four areas are rated based on quantitative and subjective substantiations. An overview of these ratings, including proformas, stating the substantiation of these ratings, are included in the appendix (Appendix A.14. The ratings, together with the predetermined weights (Table 3 and 4), serves as basis for the final scores. These final scores are presented below in table 19.

Table 19: Scores Internal / Outsource

	T& MP	SC& MP	SS	Cost	Score
Weight	25	25	25	25	100
Internal score	427	467	406	400	425
Outsource score	315	226	379	300	305
Gap	28	60	6.75	25	

As can be seen in table 19, internal production would lead to the most favourable situation. In order to obtain a clear overview of the score distribution, a GAP-analysis is included (Figure 15), showing the weighted differences for each of the areas. By doing so, the areas that contribute most to the overall score differences are highlighted. Also, areas that leap behind could be further improved.

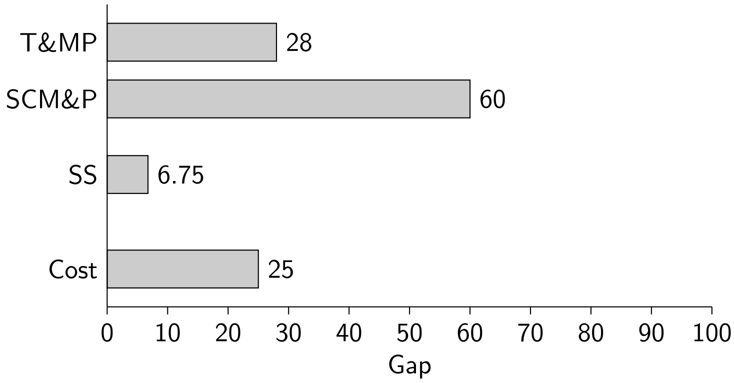

Figure 15: GAP-analysis

Interpreting the obtained results is key before determining the final decision advice. Considering the scores and GAP-analysis, it can be seen that internal production scores especially good within the area supply chain management and logistics. Reason for this is (1)the possibility to improve lead times with more than 50% and (2)increasing on-time delivery with approximately 10%, both two the most important topics within this area. Note that on-time delivery, the second most important factor is within this area, could also be improved by optimizing the communication and processes between Flowserve and the outsource companies. However, at the moment is not clear to which extent these improvements would increase delivery performance.

Then, the second largest difference is observed within the area technology and manufacturing processes. Within this area, the level of being able to obtain qualified operators and the state of machinery/equipment are key to consider. Regarding hiring the right employees, Flowserve would have an advantage due to its size and internal hiring possibilities. Furthermore, the machinery would be more state-of-the-art, enabling to automate more steps in the process. Moreover, Flowserve Etten-Leur could also expect assistance from Flowserve Kalamazoo which accelerates internal experience.

Thirdly, there is a considerable cost advantage when insourcing the process. These savings can be traced back to savings on high supplier margins maintained for rush orders, experienced by the QRC's, transport and order placements cost and ordinary production savings.

Lastly, both situations score comparable regarding support systems. The quality of delivered parts by current outsourcing companies are good. However, this is mainly based on actual reported NCMR's

(Non-Conforming Material Report). Relying on solely these NCMR's, however, is not completely reliable. In the case of smaller defects with outsourced parts, creating NCMR's are often skipped due to the time it takes to perform this action. Instead, concerned parts are repaired internally without giving notice to the system.

7.2 Sensitivity analysis

In order to make the decision advice more robust, a sensitivity analysis towards four different areas is performed (Appendix A.16). For each area, a minimal weight of zero and a maximum weight of 100 is applied. Subsequently, the adjusted final score is observed.

For the areas technology and manufacturing processes and cost, it is observed that changing their weights does not result in drastic changes in the final score and also the decision advice would not change.

Adjusting the weight of the areas supply chain management and logistics and support systems lead to larger differences in the final score. However, also these changes do not change the final decision advice.

7.3 Decision advice

Based on the results above and careful interpretation, a positive decision advice is given for insourcing the HVOF process. Regarding the two most important areas of the objective of this project (supply chain management and logistics and support systems), insourcing the project scores especially good on the former one. More specially, the total lead time could be reduced by almost 50% and there is considerable opportunity to further improve customer on-time delivery. The two other areas (technology and manufacturing processes and cost) were especially important for internal feasibility of the project. Both these areas outperform outsourcing considerately. Regarding the first one, Flowserve Etten-Leur would have the disposal over a state-of-the-art HVOF system, more opportunities to attract skilled operators and could leverage on the experience of Flowserve Kalamazoo. It also turns out that in terms of cost the project would results in savings of approximately €100,000 in the first years and increasingly more in the remaining years of the project. The estimated payback period low with a number of 2.8 years.

In this project, the included types of overlays were tungsten carbide and Colmonoy. However, there are more types of overlays that could possibly be replaced by the HVOF process. This is already common practice at the QRC where worn out overlays are replaced by new HVOF overlays. For this reason, the demand in the future could possibly be further increased. Furthermore, this study has only considered Seals, Seals QRC, PMC and PMC QRC. However, it could be further investigated if it is profitable to include more QRC's in the future. This would possibly increase savings and occupancy rate of the process even more. Furthermore, in contrast to the past, Flowserve is getting more freedom from their customers regarding the decision which type of overlay process to apply.

8 Discussion

As the results section already discussed, the decision advice regarding the HVOF process is in favor for insourcing the project. It could be seen that not only in terms of cost but also in terms of production, supply chain and quality, insourcing the process make sense to perform. By incorporating these four major areas, it is made sure that no factors are overseen, resulting in a reliably decision advice.

Regarding operating leverage and systematic risk between internal production and outsourcing, the valuation method applied in this study gave useful insights in this behavior. By using a certainty-equivalent valuation method, parameters such as the degree of operating, financial and depreciation leverage could easily be investigated after the valuation was performed. The valuation method ensured that every project could be investigated in isolation without the use/adjustment of data from other assets such as company wide beta's, DOL's, DFL's, etc.

After carrying out the valuation and carefully interpreting the results, it could be seen that outsourcing would lead to lower degree of operating leverages. This was explained by the lower fixed cost. However, this difference in favor for outsourcing diminished over time as variable cost during outsourcing increases more rapidly in comparison with internal production, resulting in a lower contribution margin and, therefore, higher degree of operating leverages. For that reason, it is clear that during valuations such as these, it is wisely to not oversee and skip effects such as these as they have a major influence on the eventually results. In this particular case study, the course of the involved parameters were quite modest and still, the degree of operating leverage increases significantly over time. It is, therefore, not hard to imagine that, in case of a more volatile project, it is even more important and essential to take into account these behaviors.

Further research could be performed towards the difference in net present values that arises between net income and free cash flow based valuations. In this particular case, both valuations leaded to a positive advice for insourcing the project. However, what if one valuations would lead to a positive advice and the other one to a negative one? Which one would be appropriate to use when the two valuation methods regarding outsourcing leads to the same net present value?

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A Appendix

A.1 Derivation DFL formula

The standard elasticity function of degree of financial leverage is

$$DFL = \frac{\%\Delta NI}{\%\Delta EBIT} \tag{27}$$

First, the numerator is further written out

$$\%\Delta NI = \frac{\Delta NI}{NI} \tag{28}$$

$$\Delta NI = (\Delta EBIT - \Delta I) * (1 - T) \tag{29}$$

Because the interest payments are fixed, the change in the interest payment is equal to zero (Δ I = 0).

$$\Delta NI = \Delta EBIT * (1 - T) \tag{30}$$

$$NI = (EBIT - I) * (1 - T) \tag{31}$$

Now, Eq.28 can be written as

$$\%\Delta NI = \frac{\Delta EBIT * (1 - T)}{(EBIT - I) * (1 - T)} \tag{32}$$

The last term (1 - T) is canceled out

$$\%\Delta NI = \frac{\Delta EBIT}{EBIT - I} \tag{33}$$

The second step is to further written out the denominator of the DFL equation (Eq.27)

$$\%\Delta EBIT = \frac{\Delta EBIT}{EBIT} \tag{34}$$

Now that every term of DFL is completely written out, the following equation is obtained

$$DFL = \frac{\frac{\Delta EBIT}{(EBIT - I)}}{\frac{\Delta EBIT}{EBIT}} = \frac{\Delta EBIT}{(EBIT - I)} * \frac{EBIT}{\Delta EBIT} \tag{35}$$

The term ΔEBIT is canceled out, resulting in

$$DFL = \frac{EBIT}{EBIT - I} \tag{36}$$

A.2 Derivation DOL formula

The standard elasticity function of degree of operating leverage is

$$DOL = \frac{\%\Delta EBIT}{\%\Delta Q} \tag{37}$$

First, the numerator is further written out

$$\%\Delta EBIT = \frac{\Delta EBIT}{EBIT} \tag{38}$$

$$\Delta EBIT = \Delta Q(p - v) - \Delta F \tag{39}$$

Because the fixed cost are constant, the change in the fixed cost is equal to zero (Δ F = 0).

$$\Delta EBIT = \Delta Q(p - v) \tag{40}$$

$$EBIT = Q(p - v) - F \tag{41}$$

Now, Eq.38 can be written as

$$\%\Delta EBIT = \frac{\Delta Q(p - v)}{Q(p - v) - F} \tag{42}$$

The second step is to further written out the denominator of the DOL equation (Eq.37)

$$\%\Delta Q = \frac{\Delta Q}{Q} \tag{43}$$

Now that every term of DOL is completely written out, the following equation is obtained

$$DOL = \frac{\frac{\Delta Q(p-v)}{Q(p-v)-F}}{\frac{\Delta Q}{Q}} = \frac{\Delta Q(p - v)}{Q(p - v) - F} * \frac{Q}{\Delta Q} \tag{44}$$

The term ΔQ is canceled out, resulting in

$$DOL = \frac{Q(p - v)}{Q(p - v) - F} \tag{45}$$

A.3 Three-years monthly returns Flowserve

THREE MONTHS

Date	Open	High	Low	Close	Adj Close	Returns	Volume
12/1/2015	46.35	46.98	40.1	42.08	40.01906		22802500
1/1/2016	41.4	42.07	33.86	38.64	36.91095	-7.76658	30076300
2/1/2016	38.05	43.6	35.25	42.02	40.1397	8.74741	30015000
3/1/2016	42.63	47.32	41.91	44.41	42.42276	5.68778	27111600
4/1/2016	43.92	49.52	41.52	48.81	46.81427	10.35179	26650500
5/1/2016	48.89	49.22	44.53	48.13	46.16208	-1.39315	22539000
6/1/2016	47.73	52.5	42.85	45.17	43.32311	-6.15001	29564700
7/1/2016	45.09	49.61	43.54	47.85	46.0694	6.339083	33796200
8/1/2016	47.58	49.66	45.27	48.37	46.57005	1.086726	20513400
9/1/2016	48.31	49	44.73	48.24	46.44489	-0.26876	18084100
10/1/2016	47.96	48.81	39.13	42.35	40.94384	-11.8442	29539800
11/1/2016	42.61	48.07	41.03	47.45	45.87451	12.04251	27270000
12/1/2016	48.13	52.08	47.64	48.05	46.45458	1.26448	26819300
1/1/2017	48.61	52.1	48.1	49.16	47.71462	2.712398	20718900
2/1/2017	49.29	51.82	46	46.45	45.08429	-5.51261	38336700
3/1/2017	47.2	48.6	44.71	48.42	46.99637	4.24112	32201800
4/1/2017	48.42	51.62	46.91	50.87	49.57998	5.497452	23749300
5/1/2017	51.06	51.92	47.48	48.5	47.27008	-4.65893	28813100
6/1/2017	48.75	49.53	43.6	46.43	45.25257	-4.26804	28892500
7/1/2017	46.85	47.59	40.24	41.13	40.25324	-11.0476	29531100
8/1/2017	41.13	42.06	37.51	39.28	38.44268	-4.49793	30566900
9/1/2017	39.4	43.65	38.99	42.59	41.68212	8.426676	25189400
10/1/2017	42.52	45.38	41.78	44.07	43.32393	3.938898	27800600
11/1/2017	44.44	44.83	37.71	42.58	41.85916	-3.38098	40423400
12/1/2017	42.65	43.87	40.19	42.13	41.41678	-1.05683	22135300
1/1/2018	42.45	46.16	42.14	45.32	44.55277	7.571796	26759300
2/1/2018	45	46.1	38.79	42.35	41.82059	-6.13247	34179800
3/1/2018	42.39	46.15	40.73	43.33	42.78834	2.314054	27124200
4/1/2018	42.99	48.1	42	44.41	44.05337	2.956483	31055200
5/1/2018	44.15	48.02	40.96	41.34	41.00802	-6.91286	34956000
6/1/2018	41.52	42.56	39.45	40.4	40.07557	-2.27382	25323600
7/1/2018	40.01	44.73	39.48	44.33	44.17965	10.24084	17293700
8/1/2018	43.61	53.17	42.68	52.12	51.94323	17.57274	29143300
9/1/2018	52.08	56.86	51.58	54.69	54.50451	4.930928	21397100
10/1/2018	54.99	55.3	43.61	45.9	45.9	-15.7868	26158900
11/1/2018	46.13	55.42	45.65	46.51	46.51	1.328967	21260300
11/20/2018	47.92	48.19	46.3	46.51	46.51	0	1230382
						0.675015	average
						52.7501	variance
						7.262926	St.dev

A.4 Three-years monthly returns Dow Jones

THREE MONTHS

Date	Open	High	Low	Close	Adj Close	Returns	Volume
12/1/2015	17719.72	17901.58	17116.73	17425.03	17425.03		2.52E+09
1/1/2016	17405.48	17405.48	15450.56	16466.3	16466.3	-5.50202	2.84E+09
2/1/2016	16453.63	16795.98	15503.01	16516.5	16516.5	0.30486	2.49E+09
3/1/2016	16545.67	17790.11	16545.67	17685.09	17685.09	7.075287	2.41E+09
4/1/2016	17661.74	18167.63	17484.23	17773.64	17773.64	0.500709	2.1E+09
5/1/2016	17783.78	17934.61	17331.07	17787.2	17787.2	0.076285	1.88E+09
6/1/2016	17754.55	18016	17063.08	17929.99	17929.99	0.802774	2.35E+09
7/1/2016	17924.24	18622.01	17713.45	18432.24	18432.24	2.801173	1.82E+09
8/1/2016	18434.5	18722.61	18247.79	18400.88	18400.88	-0.17013	1.7E+09
9/1/2016	18396.57	18551.54	17992.21	18308.15	18308.15	-0.50395	2.1E+09
10/1/2016	18279.6	18399.96	17959.95	18142.42	18142.42	-0.90523	1.79E+09
11/1/2016	18158.24	19225.29	17883.56	19123.58	19123.58	5.4081	2.11E+09
12/1/2016	19149.2	19987.63	19138.79	19762.6	19762.6	3.341527	5.95E+09
1/1/2017	19872.86	20125.58	19677.94	19864.09	19864.09	0.513547	6.48E+09
2/1/2017	19923.81	20851.33	19831.09	20812.24	20812.24	4.773188	6.19E+09
3/1/2017	20957.29	21169.11	20412.8	20663.22	20663.22	-0.71602	6.94E+09
4/1/2017	20665.17	21070.9	20379.55	20940.51	20940.51	1.341945	5.39E+09
5/1/2017	20962.73	21112.32	20553.45	21008.65	21008.65	0.325401	6.61E+09
6/1/2017	21030.55	21535.03	20994.22	21349.63	21349.63	1.623048	7.21E+09
7/1/2017	21392.3	21929.8	21279.3	21891.12	21891.12	2.536289	5.57E+09
8/1/2017	21961.42	22179.11	21600.34	21948.1	21948.1	0.26029	6.15E+09
9/1/2017	21981.77	22419.51	21709.63	22405.09	22405.09	2.08214	6.34E+09
10/1/2017	22423.47	23485.25	22416	23377.24	23377.24	4.338971	7.3E+09
11/1/2017	23442.9	24327.82	23242.75	24272.35	24272.35	3.828978	7.34E+09
12/1/2017	24305.4	24876.07	23921.9	24719.22	24719.22	1.841071	6.59E+09
1/1/2018	24809.35	26616.71	24741.7	26149.39	26149.39	5.785659	9.12E+09
2/1/2018	26083.04	26306.7	23360.29	25029.2	25029.2	-4.28381	9.45E+09
3/1/2018	25024.04	25449.15	23509.06	24103.11	24103.11	-3.70004	8.87E+09
4/1/2018	24076.6	24858.97	23344.52	24163.15	24163.15	0.249101	8.06E+09
5/1/2018	24117.29	25086.49	23531.31	24415.84	24415.84	1.045764	7.28E+09
6/1/2018	24542.09	25402.83	23997.21	24271.41	24271.41	-0.59154	7.41E+09
7/1/2018	24161.53	25587.24	24077.56	25415.19	25415.19	4.712455	5.41E+09
8/1/2018	25461.63	26167.94	24965.77	25964.82	25964.82	2.162608	5.64E+09
9/1/2018	25916.07	26769.16	25754.32	26458.31	26458.31	1.900611	5.26E+09
10/1/2018	26598.36	26951.81	24122.23	25115.76	25115.76	-5.07421	8.37E+09
11/1/2018	25142.08	26277.82	24368.98	24465.64	24465.64	-2.58849	5.02E+09
11/20/2018	24618.68	24707.26	24368.98	24465.64	24465.64	0	4.46E+08
						0.988787	average
						8.60771	variance
						2.93389	St.dev

A.5 Demand Overlay types 2012-2017

Table 20: Demand distribution 2012-2017 (sorted on type)

	Year						
Type	2012	2013	2014	2015	2016	2017	2018
x716		1	1	4		2	1
x574	2	6	2	20	3		2
x596	9	4	6	6	1		
ZA	426	452	694	724	646	773	467
x533	34	16	18	15	16	3	5
x573	28	83	55	33	51	15	13
x802	1	14	6	8	6	3	4
x541	3	1		7	2	1	2
x805	19	16	38	84	25	23	13
x872	8	22	135	117	104	149	59
x891	3	47	12	51	178	79	37
x239	26	86	95	110	107	101	37
CR	38	21	17	20	30	49	51
x592	1	3	26	13	33	5	
x882	18			48	4	13	
x862		16		12			
x536	89	113	22	14	30	78	39
x594	15	3	2	18	23	4	4
XT				8	9		
XA	51	44	41	71	45	36	37
X502	6	45	33	8	14	57	11
X593		15			8		
X697	6	4		4	6	101	20
HQ	9	18	25	25	3	116	23
HQ1	16	20	13	7	3	59	8
HQ2				12			
X371	20	64	17	10		18	13
XX94		3	6			1	
XX62							4
X766							10
Total	908	1117	1274	1449	1322	1430	1266 (forecasted)

Table 21: Demand distribution 2012-2017 (sorted on company)

	Year [units]						
	2012	2013	2014	2015	2016	2017	2018
Company 1	235	544	709	913	704	533	504
Company 2	528	515	378	297	235	421	359
Olomouc		4	139	133	312	420	162
Other	145	54	48	106	71	56	192
Total	908	1117	1274	1449	1322	1430	1266 (forecasted)

Table 22: Purchase value distribution 2012-2018 (sorted on company)

	Year [value in thousands]						
	2012	2013	2014	2015	2016	2017	2018
Company 1 + 2	€127	€167	€198	€205	€162	€158	€145
*Olomouc	€0	€1	€29	€27	€64	€87	€24
Other	€24	€9	€9	€18	€12	€9	€32
Total	€152	€176	€236	€251	€239	€255	€211 (forecasted)

**Purchase values are regarding adding overlays only. In case of Olomouc, which also manufactures the parts itself, these cost are subtracted.*

A.6 Average purchase price

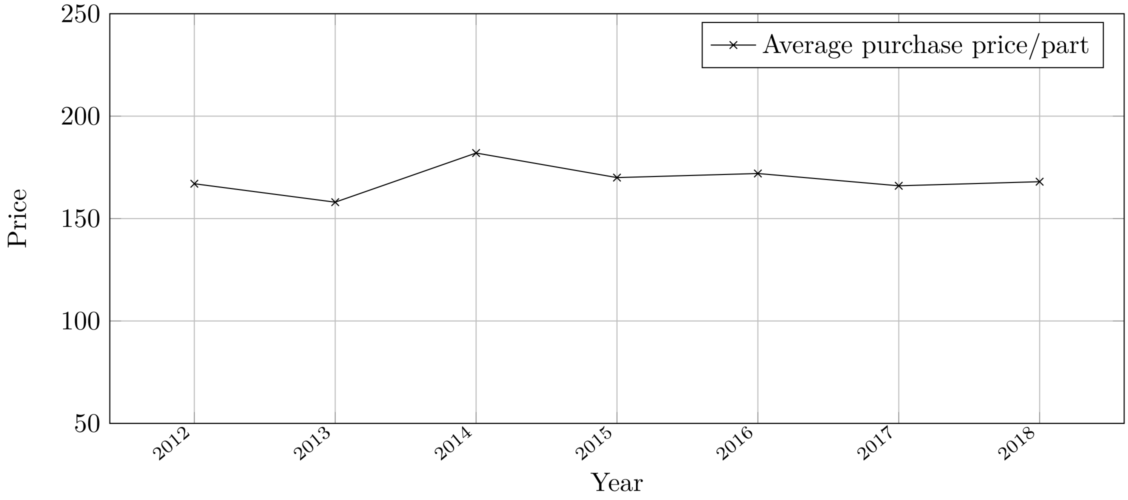


Figure 16: Average purchase price Company 1 and 2 (2012-2018)

A.7 Studer utilization rates

Table 23: Utilization rate Studer

	Utilization rate	
Date	Hours/day	Percentage/shift
2017	6.7	83.8 %
Jan 2018	5.2	65.0 %
Feb 2018	6.0	75.0 %
Mar 2018	7.1	88.75 %
Apr 2018	6.7	83.75 %
Jun 2018	5.9	73.75 %

A.8 Estimation AM/OE Share (Pegging report)

Table 24: Estimated AM/OE share

Sample	Type	Quantity	Percentage
1	Single (AM)	46	21%
	Assembly (AM)	135	62%
	New (OE)	38	17%
2	Single (AM)	41	19%
	Assembly (AM)	102	46%
	New (OE)	78	35%
3	Single (AM)	37	17%
	Assembly (AM)	110	51%
	New (OE)	68	32%
4	Single (AM)	25	14%
	Assembly (AM)	56	32%
	New (OE)	95	54%
Average	Single (AM)		18%
	Assembly (AM)		48%
	New (OE)		34%

A.9 Transportation Cost

Table 25: Estimated Transportation Cost

Company	Transport Orders	Parts	Total weight [kg]	Export(€)	Import(€)	Total(€)
1	109	397	1984	€2000	€2000	€4000
2	101	528	1612	€1750	€1750	€3500
Olomouc	221	528	2640	n/a	€10400	€10400
Total		1247				€17800

Export rate for Company 1 is €18.50/shipment
Export rate for Company 2 is €17.30/shipment
Export rate for Olomouc is €47.10/shipment

Average transportation cost Etten-Leur seals division [€/part]: approx. €15,-
Average transportation cost Etten-Leur QRC seals [€/part]: approx. €10.50

A.10 Olomouc outsource price break-down

Table 26: Olomouc Price HVOF Overlays

Step	Cost [€]	Note
Sleeve production	€150	3h*€50,-
Applying coating + transport	€170+€10	Appendix A.11
Olomouc cost	€330	Sleeve production + coating
Inter-company fee (+10%)	€33	
Transport (import)	€19.7	€10.400 / 528 parts
Total purchase price	€382.70	
Price solely for coating	€217.70	€180 + 10% Fee + Transportation

A.11 Olomouc Local Outsource Cost

Name	Item Description	Line Creation Date	Quantity	Functional Price (CZK --> Euro)
CZ OLO Operating Unit	DJ 2076488 - Item C0207967ZA - Hardlayer	2-Jan-17	1	€ 145.20
CZ OLO Operating Unit	DJ 2072640 - Item 4R10420ZA - Hardlayer	2-Jan-17	2	€ 332.00
CZ OLO Operating Unit	DJ 2062322 - Item C0323071X872 -Hardlayer	2-Jan-17	2	€ 626.40
CZ OLO Operating Unit	DJ 2072475 - Item 3R26127X536 - Hardlayer	2-Jan-17	2	€ 226.40
CZ OLO Operating Unit	DJ 2093772 - Item 3R26123X872 - Hardlayer	24-Jan-17	1	€ 76.80
CZ OLO Operating Unit	DJ 2083643 - Item 3R26123X872 - Hardlayer	24-Jan-17	2	€ 153.60
CZ OLO Operating Unit	DJ 2092397 - Item C0326942X872 - Hardlayer	23-Jan-17	2	€ 428.80
CZ OLO Operating Unit	DJ 2084439 - Item C0327115X872 - Hardlayer	24-Jan-17	3	€ 226.80
CZ OLO Operating Unit	DJ 2084440 - Item C0327892X872 - Hardlayer	24-Jan-17	2	€ 196.80
CZ OLO Operating Unit	DJ 2109220 - Item C0338065ZA - Hardlayer	16-Feb-17	12	€ 1,641.60
CZ OLO Operating Unit	DJ 2108670 - C0307413ZA - Hardlayer	17-Feb-17	4	€ 547.20
CZ OLO Operating Unit	DJ 2109219 - Item c0307413ZA - Hardlayer	17-Feb-17	8	€ 1,094.40
CZ OLO Operating Unit	DJ 2104309 - Item C0164763ZA - Hardlayer	27-Feb-17	1	€ 111.32
CZ OLO Operating Unit	DJ 2110120 - Item 3N62310X872 - Hardlayer	27-Feb-17	6	€ 1,233.60
CZ OLO Operating Unit	DJ 2115079 - Item C0338575ZA - Hardlayer	2-Mar-17	6	€ 1,029.12
CZ OLO Operating Unit	DJ 2122199 - Item C0342821ZA - Hardlayer	10-Mar-17	3	€ 450.00
CZ OLO Operating Unit	DJ 2119428 - Item C0316525ZA - Hardlayer	10-Mar-17	1	€ 107.60
CZ OLO Operating Unit	DJ 2119460 - Item C0341276ZA - Hardlayer	8-Mar-17	4	€ 916.80
CZ OLO Operating Unit	DJ 2122195 - Item 4R10430ZA1 - Hardlayer	10-Mar-17	1	€ 215.20
CZ OLO Operating Unit	DJ 2123363 - Item c0342815ZA - Hardlayer	15-Mar-17	3	€ 554.40
CZ OLO Operating Unit	DJ 2119457 - Item 2N44031ZA1 - Hardlayer	9-Mar-17	1	€ 235.60
CZ OLO Operating Unit	DJ 2115077 - Item c0338571ZA - Hardlayer	6-Mar-17	6	€ 1,389.60
CZ OLO Operating Unit	DJ 2114007 - Item C0335887ZA - Hardlayer	6-Mar-17	15	€ 2,809.80
CZ OLO Operating Unit	DJ 2114007 - Item C0335887ZA - Hardlayer	6-Mar-17	1	€ 187.32
CZ OLO Operating Unit	DJ 2132862 - Item 2N44143ZA1 - Hardlayer	27-Mar-17	1	€ 612.80
CZ OLO Operating Unit	DJ 2122162 - Item 2N44143ZA1 - Hardlayer	10-Mar-17	2	€ 1,225.60
CZ OLO Operating Unit	DJ 2133318 - Item C0335887ZA - Hardlayer	28-Mar-17	1	€ 187.32
CZ OLO Operating Unit	DJ 2134810 - Item C0269431ZA1 - Hardlayer	7-Apr-17	1	€ 165.20
CZ OLO Operating Unit	DJ 2134786 - Item C0274426ZA - Hardlayer	7-Apr-17	3	€ 525.60
CZ OLO Operating Unit	DJ 2142428 - Item 3R21813ZA - Hardlayer	12-Apr-17	1	€ 171.20
CZ OLO Operating Unit	Hardlayer	13-Apr-17	18	€ 3,204.00

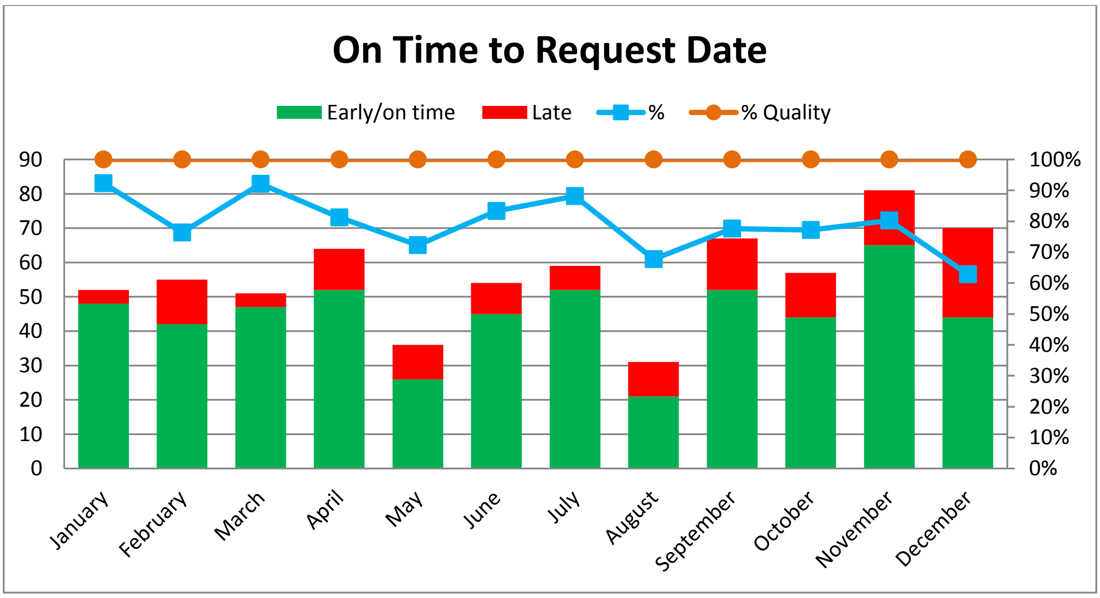
CZ OLO Operating Unit	DJ 2134795 - Item C0271532ZA - Hardlayer	19-Apr-17	3	€ 507.84
CZ OLO Operating Unit	DJ 2145920 - Item C0341347X536 - Hardlayer	24-Apr-17	1	€ 223.20
CZ OLO Operating Unit	DJ C0155627ZA - Hardlayer	28-Apr-17	1	€ 199.60
CZ OLO Operating Unit	DJ C0155627ZA - Hardlayer	28-Apr-17	1	€ 199.60
CZ OLO Operating Unit	DJ 2151031 - Item C0155627ZA - Hardlayer	3-May-17	8	€ 1,596.80
CZ OLO Operating Unit	DJ 2154711 - Item 2N46190X872 - Hardlayer	4-May-17	1	€ 78.00
CZ OLO Operating Unit	DJ 2150181 - Item 2N46190X872 - Hardlayer	4-May-17	3	€ 234.00
CZ OLO Operating Unit	DJ 2152285 - Item C0269773X536 -Hardlayer	2-May-17	2	€ 681.84
CZ OLO Operating Unit	DJ 2146501 - Item C0025974X872 - Hardlayer	10-May-17	1	€ 99.60
CZ OLO Operating Unit	DJ 2146501 - Item C0025974X872 - Hardlayer	10-May-17	1	€ 99.60
CZ OLO Operating Unit	DJ 2154712 - Item 3R26129X872 - Hardlayer	12-May-17	2	€ 299.20
CZ OLO Operating Unit	DJ 2162108 - Item 2N01481ZA - Hardlayer	15-May-17	1	€ 99.20
CZ OLO Operating Unit	DJ 2161140 - Item 2N70441ZA -Hardlayer	12-May-17	3	€ 1,599.60
CZ OLO Operating Unit	DJ Hardlayer	18-May-17	2	€ 508.80
CZ OLO Operating Unit	DJ 2168581 - Item 2N47603X872 - Hardlayer	24-May-17	1	€ 253.92
CZ OLO Operating Unit	DJ 2168812 - Item 2N47603X872Hardlayer	24-May-17	1	€ 253.92
CZ OLO Operating Unit	DJ 2172524 - Item c0084266X536 - Hardlayer	5-Jun-17	1	€ 333.60
CZ OLO Operating Unit	DJ 2174452 - Item C0147702ZA - Hardlayer	5-Jun-17	4	€ 600.00
CZ OLO Operating Unit	DJ 2174450 - Item C0147701ZA - Hardlayer	9-Jun-17	4	€ 622.40
CZ OLO Operating Unit	DJ 2181232 - Item C0338111ZA1 - Hardlayer	19-Jun-17	2	€ 737.04
CZ OLO Operating Unit	DJ 2180782 - Item C0350831X872 - Hardlayer	16-Jun-17	2	€ 190.40
CZ OLO Operating Unit	DJ 2178659 - Item C0345893X872 - Hardlayer	14-Jun-17	18	€ 1,792.80
CZ OLO Operating Unit	DJ 2182421 - Item C0350738ZA - Hardlayer	21-Jun-17	7	€ 1,579.20
CZ OLO Operating Unit	DJ 2182416 - Item C0350740ZA - Hardlayer	21-Jun-17	7	€ 1,579.20
CZ OLO Operating Unit	DJ 2182420 - Item C0350745ZA - Hardlayer	22-Jun-17	14	€ 2,721.60
CZ OLO Operating Unit	DJ 2182422 - C0354340ZA - Hardlayer	29-Jun-17	1	€ 273.40
CZ OLO Operating Unit	DJ 2203264 - Item C0307381ZA - Hardlayer	7-Aug-17	1	€ 131.60
CZ OLO Operating Unit	DJ 2203264 - Item C0307381ZA - Hardlayer	7-Aug-17	7	€ 921.20
CZ OLO Operating Unit	DJ 2203266 - Item C0307411ZA - Hardlayer	4-Aug-17	8	€ 851.20
CZ OLO Operating Unit	DJ 2217373 - Item 4R10420ZA - Hardlayer	18-Aug-17	3	€ 498.00
CZ OLO Operating Unit	DJ 2208617 - Item 4R10408ZA - Hardlayer	23-Aug-17	6	€ 595.20
CZ OLO Operating Unit	DJ 2222833 - Item C0307398ZA - Hardlayer	30-Aug-17	4	€ 1,094.40

CZ OLO Operating Unit	DJ 2222833 - Item C0307398ZA - Hardlayer	30-Aug-17	1	€ 273.60
CZ OLO Operating Unit	Hardlayer	3-Oct-17	10	€ 1,352.00
CZ OLO Operating Unit	DJ 2243809 - Item C0307416ZA - Hardlayer	9-Oct-17	1	€ 127.60
CZ OLO Operating Unit	DJ 2233829 - Item C,307416ZA - Hardlayer	9-Oct-17	17	€ 2,169.20
CZ OLO Operating Unit	DJ 2252412 - Item C0025974X872 - Hardlayer	20-Oct-17	1	€ 99.60
CZ OLO Operating Unit	DJ 2247916 - Item 3R26129X872 - Hardlayer	17-Oct-17	1	€ 149.60
CZ OLO Operating Unit	DJ 2254532 - Item 3R26124ZA - Hardlayer	6-Nov-17	1	€ 75.60
CZ OLO Operating Unit	DJ 2262806 - Item C0307377ZA - Hardlayer	21-Nov-17	6	€ 643.20
CZ OLO Operating Unit	DJ 2277878 - Item C0299395ZA - Hardlayer	4-Dec-17	1	€ 116.72
CZ OLO Operating Unit	DJ 2277878 - Item C0299395ZA - Hardlayer	30-Nov-17	2	€ 233.44
CZ OLO Operating Unit	DJ 2277058 - Item c0299389ZA - Hardlayer	30-Nov-17	4	€ 502.40
CZ OLO Operating Unit	DJ 2289805 - Item C0299395ZA - Hardlayer	18-Dec-17	1	€ 116.72

A.12 OTP Outsource company 1 and 2 (2015 - 2018)

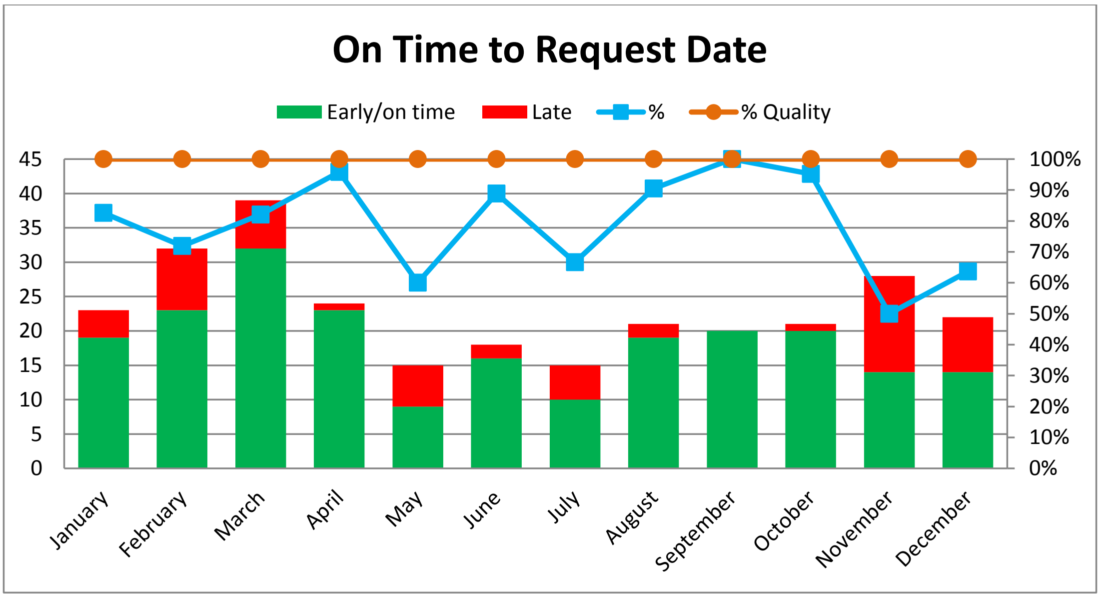
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	4	8%	48	92%	52
February	13	24%	42	76%	55
March	4	8%	47	92%	51
April	12	19%	52	81%	64
May	10	28%	26	72%	36
June	9	17%	45	83%	54
July	7	12%	52	88%	59
August	10	32%	21	68%	31
September	15	22%	52	78%	67
October	13	23%	44	77%	57
November	16	20%	65	80%	81
December	26	37%	44	63%	70
Totals:	139	21%	538	79%	677

2015 – Company 1



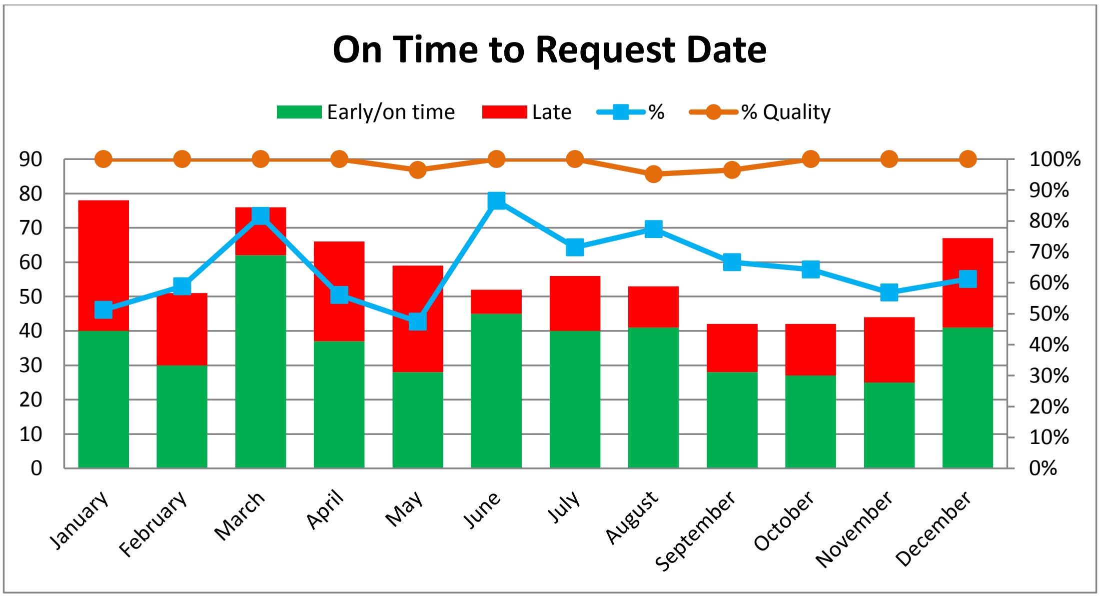
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	4	17%	19	83%	23
February	9	28%	23	72%	32
March	7	18%	32	82%	39
April	1	4%	23	96%	24
May	6	40%	9	60%	15
June	2	11%	16	89%	18
July	5	33%	10	67%	15
August	2	10%	19	90%	21
September	0	0%	20	100%	20
October	1	5%	20	95%	21
November	14	50%	14	50%	28
December	8	36%	14	64%	22
Totals:	59	21%	219	79%	278

2015 – Company 2



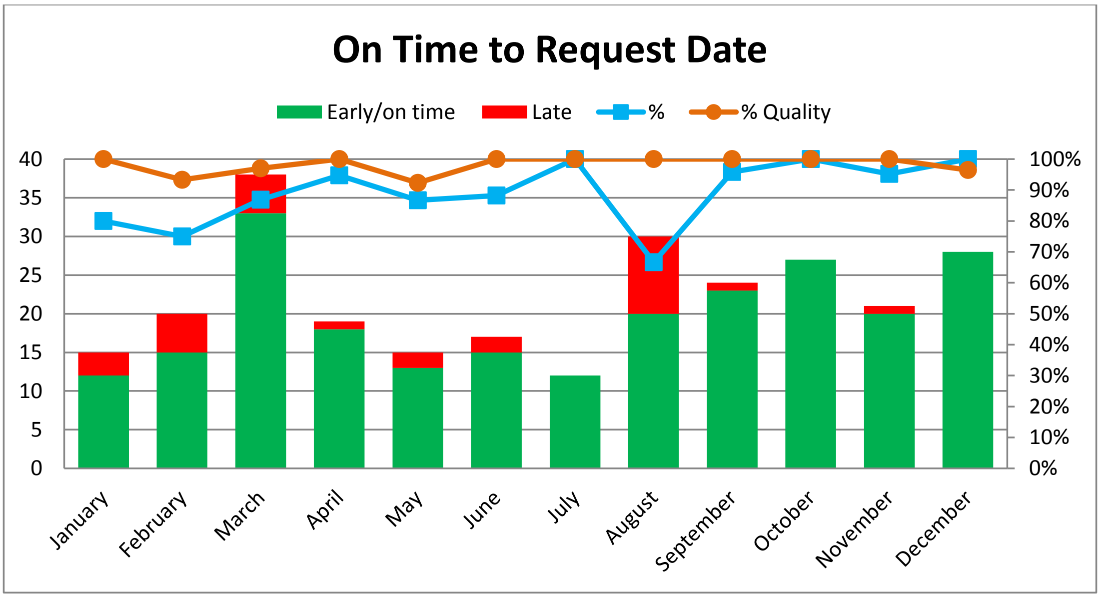
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	38	49%	40	51%	78
February	21	41%	30	59%	51
March	14	18%	62	82%	76
April	29	44%	37	56%	66
May	31	53%	28	47%	59
June	7	13%	45	87%	52
July	16	29%	40	71%	56
August	12	23%	41	77%	53
September	14	33%	28	67%	42
October	15	36%	27	64%	42
November	19	43%	25	57%	44
December	26	39%	41	61%	67
Totals:	242	35%	444	65%	686

2016 – Company 1



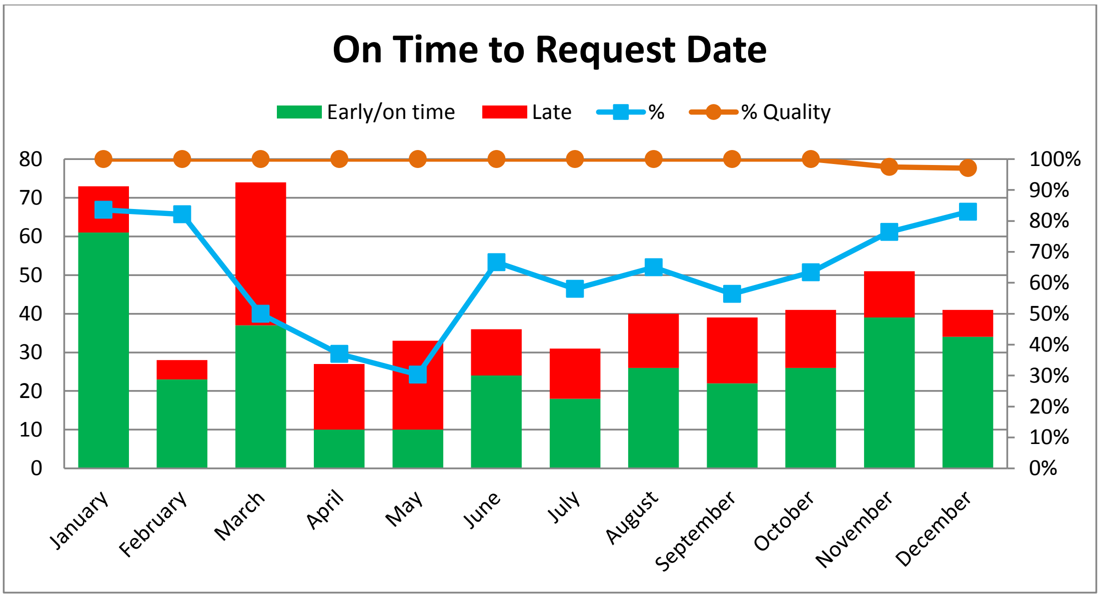
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	3	20%	12	80%	15
February	5	25%	15	75%	20
March	5	13%	33	87%	38
April	1	5%	18	95%	19
May	2	13%	13	87%	15
June	2	12%	15	88%	17
July	0	0%	12	100%	12
August	10	33%	20	67%	30
September	1	4%	23	96%	24
October	0	0%	27	100%	27
November	1	5%	20	95%	21
December	0	0%	28	100%	28
Totals:	30	11%	236	89%	266

2016 – Company 2



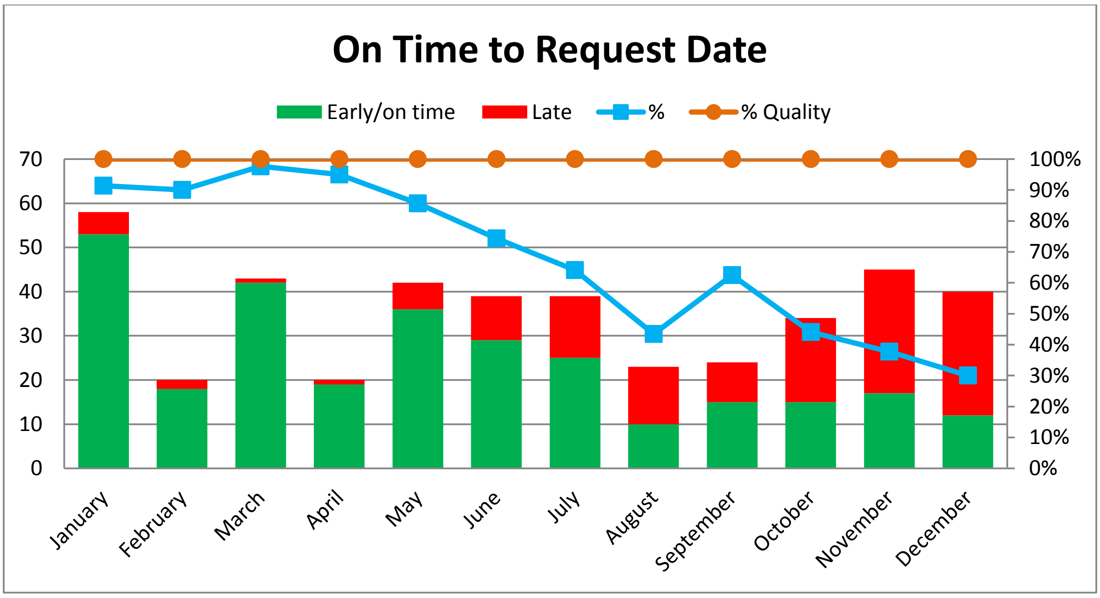
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	12	16%	61	84%	73
February	5	18%	23	82%	28
March	37	50%	37	50%	74
April	17	63%	10	37%	27
May	23	70%	10	30%	33
June	12	33%	24	67%	36
July	13	42%	18	58%	31
August	14	35%	26	65%	40
September	17	44%	22	56%	39
October	15	37%	26	63%	41
November	12	24%	39	76%	51
December	7	17%	34	83%	41
Totals:	184	37%	330	63%	514

2017 - Company 1



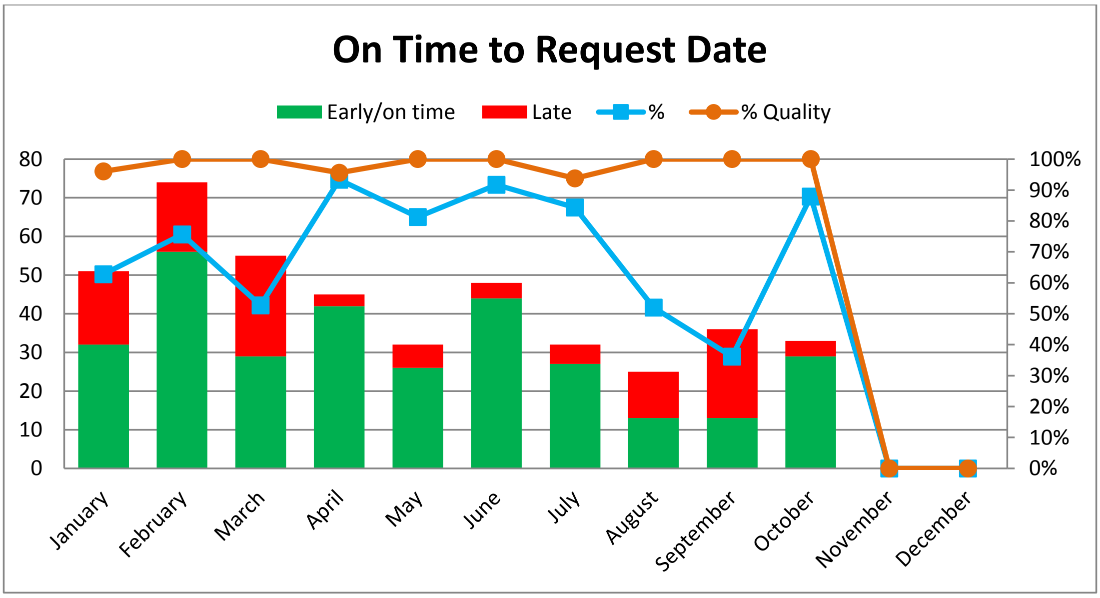
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	5	9%	53	91%	58
February	2	10%	18	90%	20
March	1	2%	42	98%	43
April	1	5%	19	95%	20
May	6	14%	36	86%	42
June	10	26%	29	74%	39
July	14	36%	25	64%	39
August	13	57%	10	43%	23
September	9	38%	15	63%	24
October	19	56%	15	44%	34
November	28	62%	17	38%	45
December	28	70%	12	30%	40
Totals:	136	32%	291	68%	427

2017 – Company 2



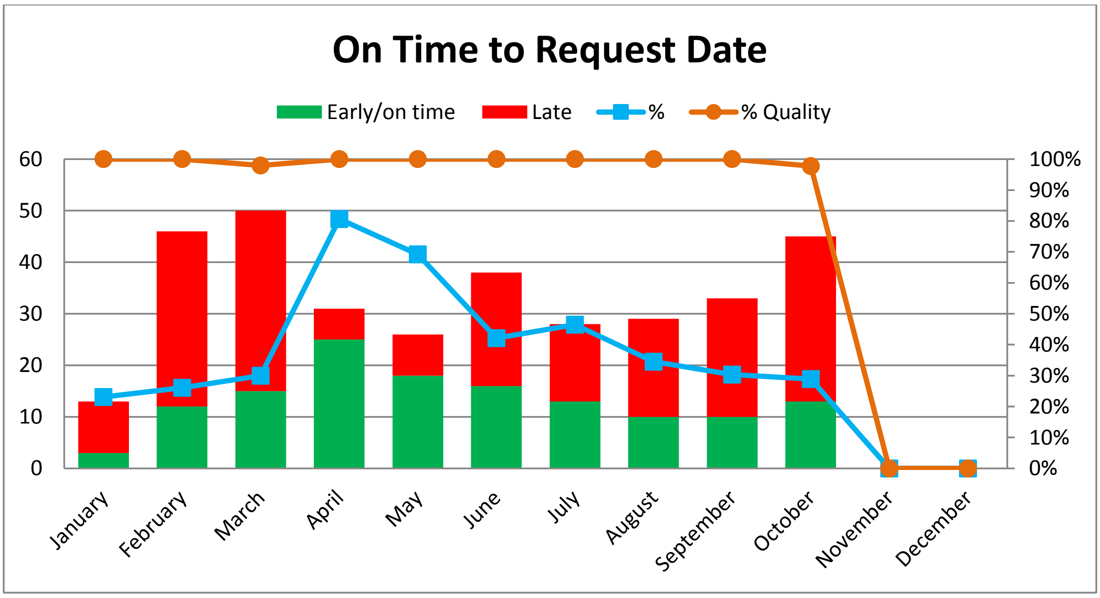
	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	10	77%	3	23%	13
February	34	74%	12	26%	46
March	35	70%	15	30%	50
April	6	19%	25	81%	31
May	8	31%	18	69%	26
June	22	58%	16	42%	38
July	15	54%	13	46%	28
August	19	66%	10	34%	29
September	23	70%	10	30%	33
October	32	71%	13	29%	45
November	0	-	0	-	0
December	0	-	0	-	0
Totals:	204	60%	135	40%	339

2018 – Company 1



	On Time to Request Date				
	Late	%	Early/on time	%	Total
January	10	77%	3	23%	13
February	34	74%	12	26%	46
March	35	70%	15	30%	50
April	6	19%	25	81%	31
May	8	31%	18	69%	26
June	22	58%	16	42%	38
July	15	54%	13	46%	28
August	19	66%	10	34%	29
September	23	70%	10	30%	33
October	32	71%	13	29%	45
November	0	-	0	-	0
December	0	-	0	-	0
Totals:	204	60%	135	40%	339

2018 – Company 2



A.13 NPV results

A.13.1 In-house production

Year	1	2	3	4	5	6	7	8	9	10
Demand	1843	1843	1843	1843	1843	1843	1843	1843	1843	1843
Selling price	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00
Variable cost	€ 145.35	€ 148.26	€ 151.22	€ 154.25	€ 157.33	€ 160.48	€ 163.69	€ 166.96	€ 170.30	€ 173.71
Fixed cost	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00
Sales	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00	€ 1,105,800.00
Variable cost total	€ 267,880.05	€ 273,237.65	€ 278,702.40	€ 284,276.45	€ 289,961.98	€ 295,761.22	€ 301,676.45	€ 307,709.97	€ 313,864.17	€ 320,141.46
Fixed cost	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00	€ 362,500.00
Depreciation	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00	€ 30,000.00
EBIT	€ 445,419.95	€ 440,062.35	€ 434,597.60	€ 429,023.55	€ 423,338.02	€ 417,538.78	€ 411,623.55	€ 405,590.03	€ 399,435.83	€ 393,158.54
Interest	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
EBT	€ 445,419.95	€ 440,062.35	€ 434,597.60	€ 429,023.55	€ 423,338.02	€ 417,538.78	€ 411,623.55	€ 405,590.03	€ 399,435.83	€ 393,158.54
Taxes	€ 89,083.99	€ 88,012.47	€ 86,919.52	€ 85,804.71	€ 84,667.60	€ 83,507.76	€ 82,324.71	€ 81,118.01	€ 79,887.17	€ 78,631.71
E[NI]	€ 356,335.96	€ 352,049.88	€ 347,678.08	€ 343,218.84	€ 338,670.42	€ 334,031.02	€ 329,298.84	€ 324,472.02	€ 319,548.66	€ 314,526.83
E[FCF]	€ 386,335.96	€ 382,049.88	€ 377,678.08	€ 373,218.84	€ 368,670.42	€ 364,031.02	€ 359,298.84	€ 354,472.02	€ 349,548.66	€ 344,526.83
Cor(Q;r_m)	0.630	0.630	0.630	0.630	0.630	0.630	0.630	0.630	0.630	0.630
St.dev[Q]	184.300	184.300	184.300	184.300	184.300	184.300	184.300	184.300	184.300	184.300
St.dev[r_M]	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
Cov(Y;r_m)	1237.373	1229.461	1221.392	1213.160	1204.764	1196.200	1187.465	1178.556	1169.467	1160.198
Cov(Y;r_m)/E[NI]	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Cov(Y;r_m)/E[FCF]	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Lambda	25.626	25.626	25.626	25.626	25.626	25.626	25.626	25.626	25.626	25.626
CEQ(NI)	€ 324,626.55	€ 291,856.24	€ 261,978.18	€ 234,762.24	€ 209,995.71	€ 187,481.97	€ 167,039.31	€ 148,499.82	€ 131,708.37	€ 116,521.65
CEQ(FCF)	€ 354,626.55	€ 321,634.83	€ 291,345.41	€ 263,556.39	€ 238,080.36	€ 214,743.32	€ 193,383.78	€ 173,851.86	€ 156,008.49	€ 139,724.61
PV(NI)	€ 309,168.15	€ 264,722.22	€ 226,306.60	€ 193,139.48	€ 164,537.14	€ 139,901.93	€ 118,711.72	€ 100,510.52	€ 84,900.39	€ 71,534.19

PV(FCF)	€ 337,739.57	€ 291,732.27	€ 251,675.12	€ 216,828.50	€ 186,542.19	€ 160,244.77	€ 137,434.24	€ 117,669.78	€ 100,564.46	€ 85,778.79
NPV(NI)	€ 1,673,432.33		€ 1,722,545.39 (incl. salvage value)							
NPV(FCF)	€ 1,586,209.70	€ 49,113.06 (pv(salvage value))	€ 1,635,322.76 (incl. salvage value present value)							

DOL	1.88	1.89	1.90	1.91	1.93	1.94	1.95	1.97	1.98	2.00
DFL	1	1	1	1	1	1	1	1	1	1
Beta, sales	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Project beta (NI)(Mandelker)	4.04	4.07	4.09	4.12	4.14	4.17	4.20	4.23	4.26	4.30
Project beta (NI)	4.04	4.07	4.09	4.12	4.14	4.17	4.20	4.23	4.26	4.30
DDL	0.922	0.921	0.921	0.920	0.919	0.918	0.917	0.915	0.914	0.913
Project beta (FCF)(Mandelker)	3.73	3.75	3.77	3.79	3.81	3.83	3.85	3.87	3.90	3.92
Project beta (FCF)	3.73	3.75	3.77	3.79	3.81	3.83	3.85	3.87	3.90	3.92
Discount rate (NI)	15%	15%	15%	15%	16%	16%	16%	16%	16%	16%
Discount rate (FCF)	14%	14%	14%	15%	15%	15%	15%	15%	15%	15%
Discount for risk (NI)	€ 31,709.41	€ 60,193.64	€ 85,699.90	€ 108,456.59	€ 128,674.70	€ 146,549.05	€ 162,259.53	€ 175,972.20	€ 187,840.29	€ 198,005.18
Discount for risk (FCF)	€ 31,709.41	€ 60,415.05	€ 86,332.67	€ 109,662.45	€ 130,590.06	€ 149,287.71	€ 165,915.07	€ 180,620.16	€ 193,540.17	€ 204,802.22

A.13.2 Outsourcing

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Demand	1850	1850	1850	1850	1850	1850	1850	1850	1850	1850
Selling price	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00	€ 600.00
Variable cost	€ 339.15	€ 345.93	€ 352.85	€ 359.91	€ 367.11	€ 374.45	€ 381.94	€ 389.58	€ 397.37	€ 405.32
Fixed cost	164000	164000	164000	164000	164000	164000	164000	164000	164000	164000
Sales	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00	€ 1,110,000.00
Variable cost total	€ 627,427.50	€ 639,976.05	€ 652,775.57	€ 665,831.08	€ 679,147.70	€ 692,730.66	€ 706,585.27	€ 720,716.98	€ 735,131.32	€ 749,833.94
Fixed cost	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00	€ 164,000.00
Depreciation	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
EBIT	€ 318,572.50	€ 306,023.95	€ 293,224.43	€ 280,168.92	€ 266,852.30	€ 253,269.34	€ 239,414.73	€ 225,283.02	€ 210,868.68	€ 196,166.06
Interest	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
EBT	€ 318,572.50	€ 306,023.95	€ 293,224.43	€ 280,168.92	€ 266,852.30	€ 253,269.34	€ 239,414.73	€ 225,283.02	€ 210,868.68	€ 196,166.06
Taxes	€ 63,714.50	€ 61,204.79	€ 58,644.89	€ 56,033.78	€ 53,370.46	€ 50,653.87	€ 47,882.95	€ 45,056.60	€ 42,173.74	€ 39,233.21
E[NI]	€ 254,858.00	€ 244,819.16	€ 234,579.54	€ 224,135.13	€ 213,481.84	€ 202,615.47	€ 191,531.78	€ 180,226.42	€ 168,694.95	€ 156,932.85
E[FCF]	€ 254,858.00	€ 244,819.16	€ 234,579.54	€ 224,135.13	€ 213,481.84	€ 202,615.47	€ 191,531.78	€ 180,226.42	€ 168,694.95	€ 156,932.85
Cor(Q;r_m)	0.630	0.630	0.630	0.630	0.630	0.630	0.630	0.630	0.630	0.630
St.dev[Q]	185.000	185.000	185.000	185.000	185.000	185.000	185.000	185.000	185.000	185.000
St.dev[r_M]	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
Cov(NI/FCF;r_m)	712.624	694.094	675.192	655.913	636.248	616.190	595.731	574.862	553.576	531.864
Cov(NI/FCF;r_m)/E[NI]	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Cov(NI/FCF;r_m)/E[FCF]	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Lambda	25.626	25.626	25.626	25.626	25.626	25.626	25.626	25.626	25.626	25.626
CEQ(NI)	€ 236,596.01	€ 210,537.23	€ 186,405.95	€ 164,092.61	€ 143,495.59	€ 124,521.23	€ 107,083.77	€ 91,105.63	€ 76,517.74	€ 63,260.21
CEQ(FCF)	€ 236,596.01	€ 210,537.23	€ 186,405.95	€ 164,092.61	€ 143,495.59	€ 124,521.23	€ 107,083.77	€ 91,105.63	€ 76,517.74	€ 63,260.21
PV(NI)	€ 225,329.53	€ 190,963.48	€ 161,024.47	€ 134,999.39	€ 112,432.55	€ 92,919.66	€ 76,102.44	€ 61,663.88	€ 49,324.02	€ 38,836.28

A.13.3 Outsourcing

PV(FCF)	€ 225,329.53	€ 190,963.48	€ 161,024.47	€ 134,999.39	€ 112,432.55	€ 92,919.66	€ 76,102.44	€ 61,663.88	€ 49,324.02	€ 38,836.28
NPV(NI)	€ 1,143,595.69									
NPV(FCF)	€ 1,143,595.69									

DOL	1.51	1.54	1.56	1.59	1.61	1.65	1.69	1.73	1.78	1.84
DFL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Beta, sales	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Project beta (NI)(Mandelker)	3.26	3.30	3.35	3.41	3.47	3.54	3.62	3.72	3.82	3.95
Project beta (NI)	3.26	3.30	3.35	3.41	3.47	3.54	3.62	3.72	3.82	3.95
DDL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Project beta (FCF)(Mandelker)	3.26	3.30	3.35	3.41	3.47	3.54	3.62	3.72	3.82	3.95
Project beta (FCF)	3.26	3.30	3.35	3.41	3.47	3.54	3.62	3.72	3.82	3.95
Discount rate (NI)	13%	13%	13%	14%	14%	14%	14%	14%	15%	15%
Discount rate (FCF)	13%	13%	13%	14%	14%	14%	14%	14%	15%	15%
Discount for risk (NI)	€ 18,261.99	€ 34,281.93	€ 48,173.59	€ 60,042.53	€ 69,986.24	€ 78,094.25	€ 84,448.01	€ 89,120.79	€ 92,177.21	€ 93,672.64
Discount for risk (FCF)	€ 18,261.99	€ 34,281.93	€ 48,173.59	€ 60,042.53	€ 69,986.24	€ 78,094.25	€ 84,448.01	€ 89,120.79	€ 92,177.21	€ 93,672.64

A.14 Ratings

A.14.1 Rating Internal and Outsource performance

Table 27: Rating internal and outsource performance

	Rating	
	Internal	Outsource
Technology and manufacturing processes		
1. Availability of skilled operators	●●●●○	●●●○○
2. Machinery/ equipment	●●●●●	●●●○○
3. Technical support	●●●●○	●●●●○
4. Handling volume changes	●●●●○	●●●○○
Supply chain management and Logistics		
1. Lead time	●●●●●	●○○○○
2. On-time delivery performance	●●●●○	●●●○○
3. Material flow performance	●●●●●	●●●●●
4. Information system	●●●●○	●●●○○
Cost		
1. NPV-analysis	●●●●○	●●●○○
Support Systems		
1. Corporate requirements	●●●●○	●●●●○
2. Quality performance	●●●●○	●●●●○
3. Training	●●●●○	●●●○○
4. CIP	●●●●●	●●●○○

A.14.2 Pro formas (rating scales)

Table 28: T&MP rating scale

	Rating				
	1	2	3	4	5
1. Availability of operators	Never has operators	Regularly no operators	Sometimes no operators	Rarely no operators	Always has operators
2. Machinery/equipment	Poor/Old/high break down		Average/sometime break down		New/Modern/low break down
3. Technical support	Poor support		Standard support		Excellent support
4. Handling volume changes	Poor/inert handling		Average handling		Perfect/efficient handling

Table 29: SCM&P rating scale

	Rating				
	1	2	3	4	5
1. Lead time	50% increase	25% increase	No difference	25% decrease	50% increase
2. OTP	25% decrease	10% decrease	No difference	10% increase	25% increase
3. Material flow performance	Always supply interruption	Often supply interruption	Sometimes supply interruption	Rarely supply interruption	Always supply
4. Information system	Always uncertainties	Often uncertainties	Sometimes uncertainties	Rarely uncertainties	Never uncertainties

Table 30: Cost rating scale

	Rating				
	1	2	3	4	5
1. Cost savings	50% increase	25% increase	No difference	25% decrease	50% decrease

Table 31: Support systems rating scale

	Rating				
	1	2	3	4	5
1. Corporate requirements	Never meet requirements	Often don't meet requirements	Sometimes don't meet requirements	Rarely don't meet requirements	Always meet requirements
2. Quality performance	10% decrease	5% decrease	No difference	5% increase	10% increase
3. Training	No training capabilities		Average training capabilities		Excellent training capabilities
4. CIP	No attention	Rarely attention	Sometimes attention	Regularly attention	Often attention

A.15 Scores

Table 32: Score - T&MP systems

			Internal		Outsource	
Factor	Description	Weight	Score	WScore	Score	WScore
1	Availability of skilled operators	52	4	208	3	156
2	Machinery/equipment	27	5	135	3	81
3	Technical support	15	4	60	4	60
4	Handling volume changes	6	4	24	3	18
	Total			427		315

Table 33: Score - SCM&P

			Inhouse		Outsource	
Factor	Description	Weight	Score	WScore	Score	WScore
1	Lead time	52	5	260	1	52
2	On-time delivery performance	27	4	108	3	81
3	Material flow performance	15	5	75	5	75
4	Information system	6	4	24	3	18
	Total			467		226

Table 34: Score - Cost

			Inhouse		Outsource	
Factor	Description	Weight	Score	WScore	Score	WScore
1	NPV-analysis	100	4	400	3	300
	Total			400		300

Table 35: Score - Support systems

			Inhouse		Outsource	
Factor	Description	Weight	Score	WScore	Score	WScore
1	Corporate requirements	52	4	208	4	208
2	Quality control	27	4	108	4	108
3	Training	15	4	60	3	45
4	CIP	6	5	30	3	18
	Total			406		379

A.16 Sensitivity analysis decision framework

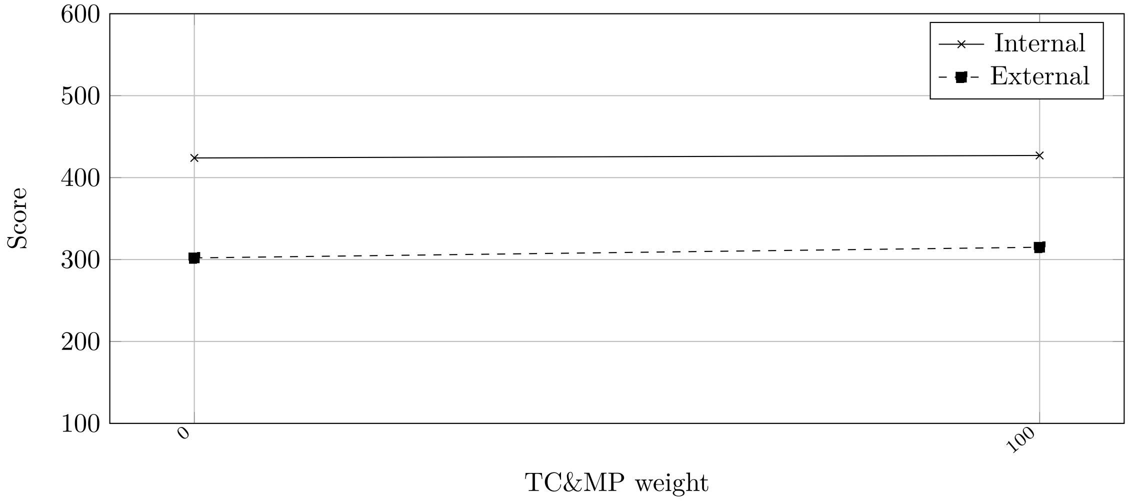


Figure 17: Sensitivity T&MP Weight

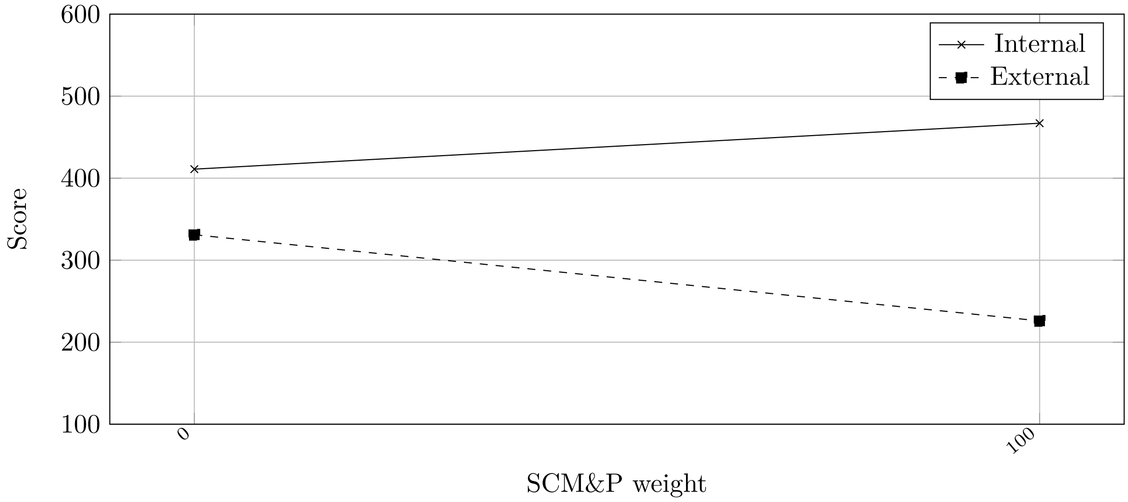


Figure 18: Sensitivity SCM&P Weight

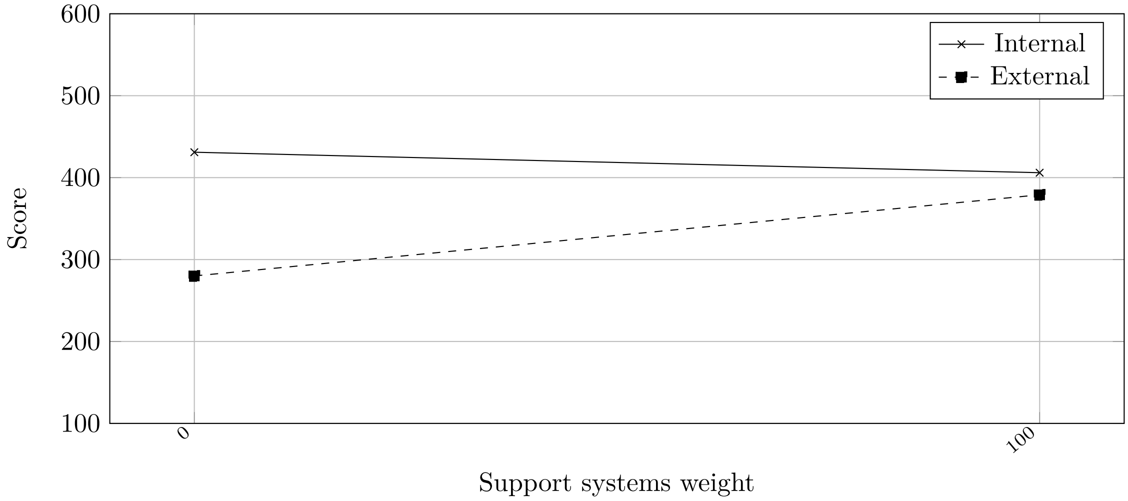


Figure 19: Sensitivity Support Systems Weight

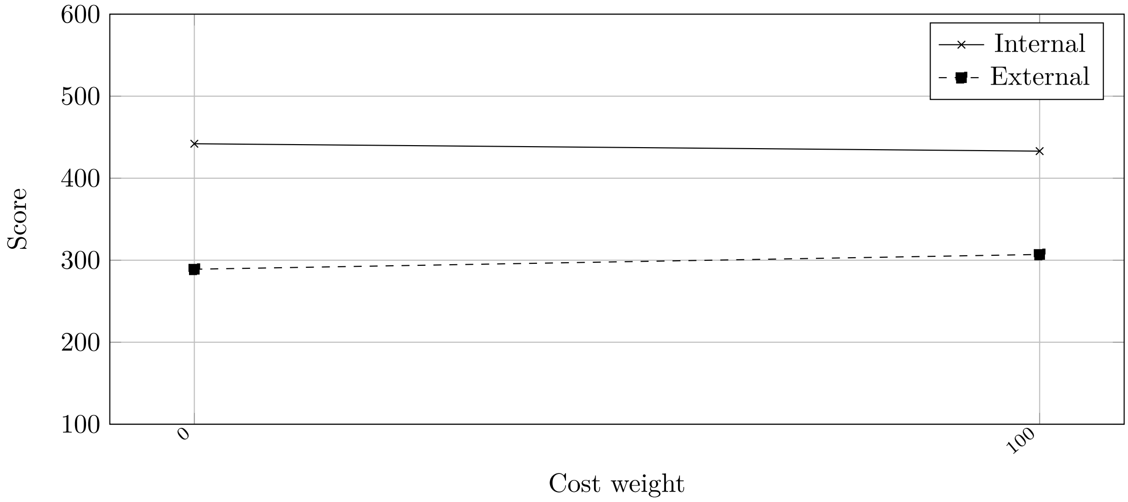


Figure 20: Sensitivity Cost Weight