Is the implementation of material T feasible, in technical and financial terms?

At Company X

Confidential summary
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Preface

Dear reader,

In front of you lies the confidential summary of the thesis: “Is the implementation of material T feasible, in technical and financial terms?”. This thesis has been conducted at company X as finalization of my bachelor program Industrial Engineering and Management.

My gratefulness for conducting and supporting this thesis mainly go out to my two supervisors, Wouter van Heeswijk and the representative from company X!

The representative of company X’s input concerning the content of this thesis was very constructive, also the valuable input on possible pitfalls during my research were very much appreciated. He really helped me to keep overview in the relatively complex environment of additive manufacturing, a sector which was quite new to me when I started orientating on my assignment. Thanks!

Wouter’s help in assessing my work on quality was very much appreciated, it really helped me understand the lacks of my report. Also, the frequent reminder of explaining my findings more solely, was helpful since the content covered was mostly not that straight-forward. Thanks!

The nature of this thesis was not a typical IEM topic, which meant that I needed some time to become familiar with the topics driving the additive manufacturing sector. I really enjoyed being part of the company X team, where all co-workers were eager to support me. I hope to give company X the first orientation on the interesting market of material T through my thesis.

I hope you enjoy reading this confidential summary!

Naud Keen

Enschede, August 2021

Glossary

Before diving into the content that I will present in this confidential summary, I want to point out that due to the confidential nature of my assignment I am not able to present all the findings from my research. In this confidential summary some text parts are intentionally left blank or a variable is used this make sure no sensitive information is leaked.

To ease the reading through this confidential summary I want to point out the following:

- **Company X**: The company where my thesis was executed
- **Material P**: The currently used material by company X
- **Material T**: The material that is investigated in my thesis and is assessed on feasibility
- **Supplier B**: The company that will supply material T to company X

1. Main topic and purpose of the thesis

In this chapter I will introduce the main topic and purpose that is covered in the thesis. I will start with the problem context in section 1.1. Then, I will explain how this problem context is translated into three cases I will solve in section 1.2. After that, I will give the action problem accompanied by the problem cluster and the research motivation, in section 1.3. In section 1.4 I will describe the discrepancy between norm and reality, this is used as a tool to assess to which degree the action problem is solved. Conclusively, I will summarize the main topics of the thesis that are covered.

1.1 Problem context

At the moment company X uses additive manufacturing to print many diverse products using material P. But with the focus on growth in mind for the upcoming year, company X wants to investigate what the opportunities are for material T, a material that has better material properties than material P, but it could be that material T is harder to process. "What are the current opportunities for material T, and are those opportunities worth the price tag of implementation?" This was the first iteration of my research question that arose during the first meeting with company X, when they expressed their desire to expand in the additive manufacturing market. This was in the end iterated to the following main research question: **"Is the adoption of material T feasible, in technical and financial terms?"**.

The technical and financial side of this research complement each other in the form of the adjustments to the machinery of company X to use material T and the possible profitability of the reached products with material T, respectively.

1.2 Division of three cases

In this section, I will explain which three cases underlie the main research question and what will be researched in each cases specifically. In section 1.2.1 I will explain the technical case and in section 1.2.2 I will explain the commercial case. To conclude, I will explain the feasibility case in section 1.2.3.

In the thesis the main research question is divided into three smaller cases, namely the technical case, the commercial case and the feasibility case. The technical case and the commercial case are two cases that require individual research in or outside company X and can be seen as independent from each other. This research for both cases is done in the form of scientific research, interviews or questionnaires. Then, the feasibility case can be seen as a conclusion of both cases, where the individual outcomes are combined into a feasibility conclusion on the feasibility of implementation of material T.

1.2.1 Technical case

The technical case will be used to gain insight into the internal investment that will be needed to adjust the machinery of company X to be compatible with material T. This will be divided in (i) the initial investment needed in hardware to get the printer compatible with material T and (ii) the initial investment in process development to get the printer compatible with material T. These two parts, the hardware and process development, always go hand in hand when adopting a material for the machinery. Therefore, these two parts form the full internal investment that needs to be made to get the machinery compatible with material T. Being compatible with material T means that the machinery can print a qualitatively sufficient material T product. The technical case will be explained in section 2.1, in research questions 1 and 2.

1.2.2 Commercial case

The commercial case is intended to get a broader perspective of the market where material T is currently applied, also to gain insight in a possible Unique Selling Point (USP) and what the potential of the material T market is for additive manufacturing. This case consists of two parts, first (i) a research about the current market of material T, where its current applications are mapped and

concluded what unique value company X can add to this market. Second, (ii) a sketch of the possible profitability of the material T market, in the form of using a benchmark part for which the margins are approximated, to gain insight in the financial potential added value of a representative material T part. These two parts combined, form the attractiveness of the market of material T, one qualitative component and one quantitative component. The commercial case will be explained in section 2.1, in research questions 3 and 4.

1.2.3 Feasibility case

I will use the Feasibility case to conclude on the previous cases and recommended to company X if there is a justification for the investment and if this will be worth it. I will do this in the form of weighting the full internal investment from the technical case against the profitability of the benchmark from the commercial case. The value that I will use to base this decision on is the payback period of the initial investment in adapting the machinery to material T. Based on this, the conclusion will be made in the form of a recommendation that supports the implementation based on the cases or dissuades the implementation.

1.3 Problem cluster, action problem and research motivation

First, I will explain the problem cluster and the action problem that is derived from it. Afterwards, I will give the motivation for the research done.

1.3.1 Problem cluster and action problem

In figure 1, I made a problem cluster. Before we mention more about this it is wise to explain some terms upfront, where two stand out, namely a knowledge problem and an action problem.

The definition of a knowledge problem is as follows:

“A knowledge problem is a description of the research population, the variables and, if necessary, the relations that need to be investigated.” (Heerkens, H., van Winden, A., 2017)

The definition of an action problem is as follows: “An action problem is a discrepancy between the norm and the reality, as perceived by the problem owner” (Heerkens, H., van Winden, A., 2017)

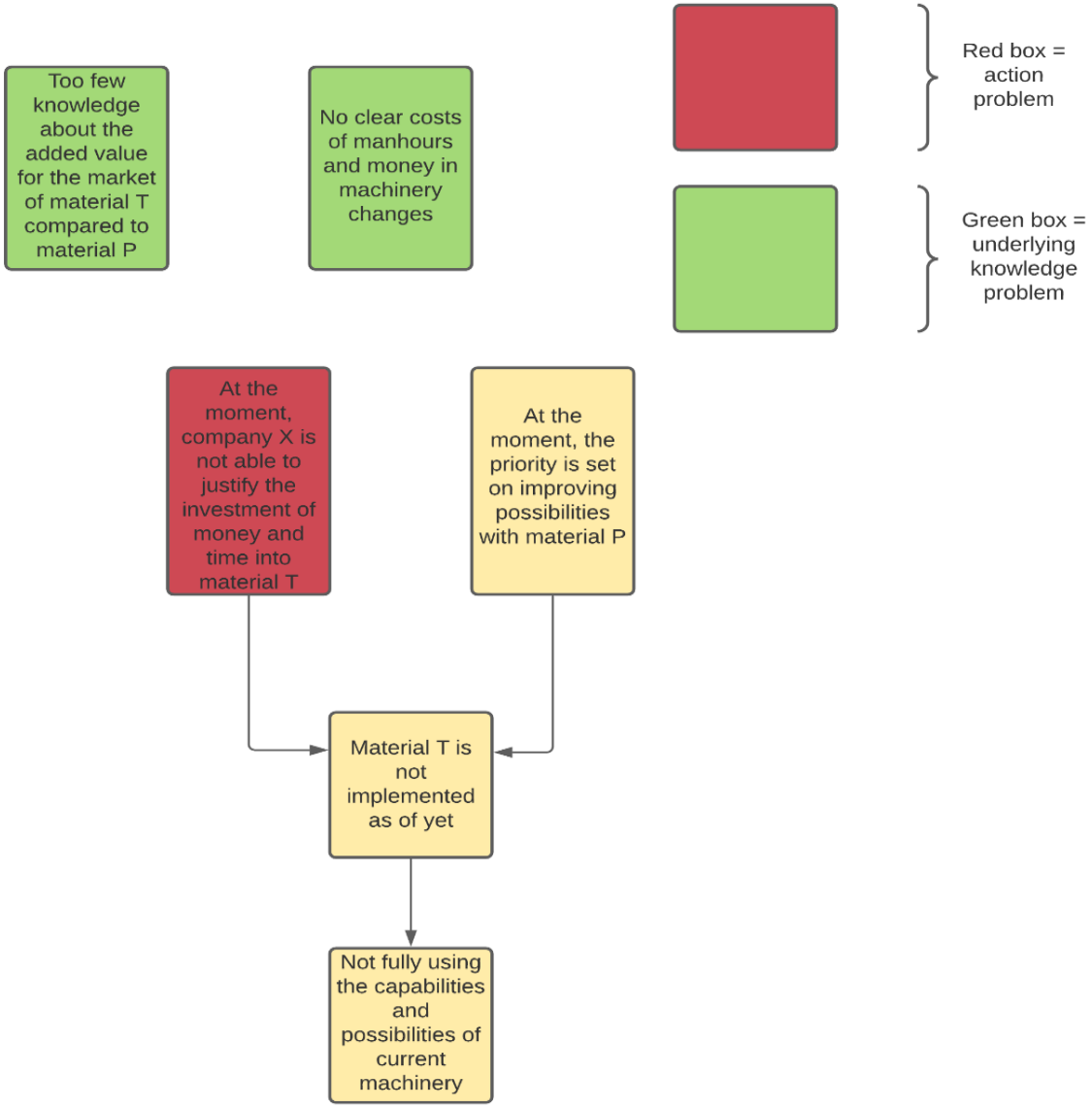

Figure 1: Problem cluster, the red box is the investigated action problem.

When we start at the bottom of figure 1, this is the current situation at company X. Company X knows their machinery can do more than additive manufacturing material P parts with amazing properties and functionalities. This already is unique, other part production methods can bring amazing properties as well but combining this with the freedom of design of additive manufacturing is currently scarcely present. Therefore, this combination is it that can currently be seen as company X's main unique selling point for the additive manufacturing market.

Company X wants to further investigate the possibilities in the form of a new material, a higher quality one, material T. The reason that this is not done yet, consists of two pieces, namely the fact that they want to further explore their possibilities with material P first, so exploring other materials is not a priority, and the justification is not there at the moment if material T is worth the money and time invested in it. My core problem, the red filled box in figure 1, will focus on the justification of time and money.

From this description one action problem can be derived, namely: “At the moment, company X is not able to justify the investment of money and time into material T”. Within the scope of my research, this action problem is not caused by any other problem and therefore this action problem is a suitable one. This action problem is caused by two underlying knowledge problems, the commercial and technical case (the green boxes), which I explain in chapter 2. The other case, the feasibility case, can be considered as a conclusion on these two cases and is therefore not to be found in the problem cluster. When these two independent knowledge questions are answered, in the form of answering all the sub questions that are formulated in chapter 2, then there is a good foundation to answer the action problem.

Of course, more aspects are of importance in this research to make a well-argued decision on the implementation of material T. But other influence factors are considered out of scope, mainly due to expressed importance of this part of the research from my supervisor and due to the limited time of only ten weeks for my research.

1.3.2 Research motivation

Due to the big willingness of company X to stay ahead of their competitors, they want to further exploit this potential key differentiator in the market. When company X will be able to additive manufacture material T, some great opportunities will potentially open-up in different niche markets. Since material T is one of the harder processable materials and company X is aiming to leave the material intact, which will make the company unique, they will gain a great advantage over competitors. However, it is of the highest importance that on the demand-side there is a real demand for the specific advantages of material T, and that on the supply-side it will be worth the investment to be able to print material T. Given this motivation, I will investigate this consideration of technical and financial aspects in the form of my thesis.

1.4 Summary of the introduction

To summarize this chapter, in this thesis I will investigate the following research question: **“Is the implementation of material T feasible, in technical and financial terms?”**. I will answer this research question via solving the technical case, the commercial case and the feasibility case. This thesis is conducted due to the expressed importance of investigating the material T, which could be a key differentiator for company X in the market. The quality of this thesis will be assessed based on the extent to which my three cases are fully answered, since this is seen as the perceived gap between norm and reality.

2 Research design

In this chapter I will explain the approach that is taken in this research. First, I will cover the research questions and the overall approach in section 2.1, the combination of these research questions will answer the main research question in the end. Then, in section 2.2 I will clarify the deliverables of this research.

2.1 Research questions and approach

In this section I will consider the cases that were introduced in section 1.2. The technical case can be found in the form of the knowledge questions 1 and 2. The commercial case is defined in knowledge questions 3 and 4. The feasibility case will be the conclusion of these two cases and is formed in the main research question. This last conclusion, is answered in chapter 6 the conclusion of the thesis.

1. "What would be the initial investment in hardware changes to the current machinery to be compatible with material T?"

In this sub-question, I will investigate what the needed hardware for material T compatible machinery should be, because then, and only then, the connection between the initial and aspired situation can be made. The current machinery is using material P, so the initial state is known. Then the categorization begins, which parts of the machinery need to be changed and what costs are accompanied by this change. Via interviews with the CTO and the leader of the process department of company X, I will gain insight in the specific adjustments. Also, a meeting will be organised with a potential supplier of material T, who can tell more about material T itself and what possible changes the material will bring to the hardware of the machinery. After this, I will connect the costs that are involved with the gathered changes that have to be made, these can be acquired internally.

2. "What would be the initial investment in process development to the current machinery to be compatible with material T"

Again, the initial situation is a material P-compatible printer. Currently, there is a lot of information present, in the form of the roadmap of past few years in the implementation of material P. I will combine this initial situation with the already present knowledge to ease the implementation of material T, because there are many similarities in the steps taken, according to the CTO of company X. This is mainly in the form of experience and developed testing methods, which could speed up the implementation of material T now. Since, mainly the comparison with material P will be used for the presumed investment of time to develop and test, there will be made an approximation for each "Bucket" of processing material T. A "Bucket" can be defined as one processing step that needs to be finetuned to gain an optimal end-result in the form of the produced material T part. I will identify the buckets for material T and add the approximated amount of time to developing each bucket. Then the costs in FTEs can be connected to this amount of invested time, to conclude on this research question.

3. "What are material T's current applications and what value can company X add here that is unique?"

The chronological order that is used in this research question is also the way of approaching this quite extensive sub-question. First, via an extensive internet research I will map what the current applications are of material T and how that is shaped in those products. After that, the connection between what currently is done with material T and what company X can do with material T will be used to concretize the similarities and differences between them. From this, the value that company X can add to this market will be explained, in the form of how to add value to current applications, and in the form of out of the box applications where company X's production methods have unique benefits, which other methods lack.

4. "What is the estimated market potential of additive manufacturing material T for company X?"

I will approach this research question through the usage of a benchmark part. This part will be used to indicate the cost-price and the sell price of a part that represents the superior material advantages of material T. To compare the profitability of such a part, the calculations will be done for material P and material T. The difference here, between cost-price and sell price for both materials, then will be used to calculate the expected margin on both parts. Again, as done in other research questions, we will make use of some models that were used in the implementation of material P, since this is good reference material. The model I will use is the price calculation model that is currently used by company X for material P parts. To make it appropriate for material T, the model will be adjusted to the material specifics of material T. From this, the cost-price and sell price can be determined. This will be used, to determine the profitability of material T.

2.2 Deliverables

Based on the previous sections, which described the division in knowledges questions and the approach of the research. I came to the selection of the following deliverables:

- A report containing research for company X that covers the answer and road to answer of the four research questions:
    - *"What would be the initial investment in hardware changes to the current machinery to be compatible with material T?"*
    - *"What would be the initial investment in process development to the current machinery to be compatible with material T"*
    - *"What are material T's current applications and what value can company X add here that is unique?"*
    - *"What is the estimated market potential of additive manufacturing material T for company X?"*
- A feasibility analysis that concludes on the main research question

3 Literature

In this chapter I will present the literature that is used during my research and the path to finding the sources. Unfortunately, due to confidentiality reasons I will not be able to present the full literature review. I will start with defining key concepts that will help me finding my sources. Then, I will present the list of used references and what kind of information it supplied.

3.1 Key concepts

The key points that I want to gain more knowledge about are the following:

- Insight in competitors for company X in the market of material T
- What the current applications of material T are
- What the current processing methods of material T are
- The advantages and disadvantages of the processing method of company X
- The difference in material properties of material P and T
- The most appropriate way to assess the feasibility case

This translates into the following key concepts:

- Focus areas
- Additive manufacturing
- Future
- Applications
- Advantages
- Disadvantages
- Production methods
- Material P
- Material T
- Feasibility
- Assessment
- Properties

3.2 Inclusion and exclusion criteria

To narrow and broaden my search of relevant sources, I defined some inclusion and exclusion criteria.

Inclusion criteria

- *Scientific Journals, Articles and Books*
  Only these types of sources will be used, to prevent using sources like fora or discussion sites.

Exclusion criteria

- *No other than English, Dutch sources*
  These are the languages which I can understand.

- *Not accessible and not free sources*
  I will only use sources that are available freely or sources that are consultable via the University Library (LISA)

3.3 Databases

The databases that will be used are Scopus, Web of Science and Google Scholar. The reason for this is that overall, they contain many sources. Which will increase the chance of finding some specific articles that are applicable. As explained by Peter Noort in the micro lectures about the SLR.

3.4 Search terms and strategy

To make sure I make use of the most relevant sources, I will only use sources if one or more key concepts are present in the title or abstract of the source. This is done to make sure to filter on only applicable sources.

Based on the earlier defined key concepts I defined the following search strings:

- “Application” AND Material P
- “Application” AND Material T
- (“Additive manufacturing” OR “3D printing”) AND (“Focus area” OR “Priority area” OR “Exploration area”) AND (Future OR Later OR Perspective)
- ("Additive manufacturing" OR "3D printing") AND ("Focus area" OR "Priority area" OR "Exploration area" OR sector OR "Exploration sector") AND (Expectation OR Perspective OR Outlook OR Prospect)
- “Feasibility” AND Assessment
- (“Advantages” OR Disadvantages”) AND Production methods AND (Material P OR Material T)
- “Properties” AND (Material P OR Material T)

3.5 Conceptual Matrix

Once I selected the right sources, I read them all and categorised them in the object section based on if the source contained interesting information about material properties, applications of material P and material T, focus areas for the future for additive manufacturing, ways to assess the feasibility case or advantages or disadvantages of the production methods of both materials.

Based on the given, I decided to select the following sources for my literature review:

Table 1: Conceptual matrix

Source	Authors	Year	Object	Key findings on focus areas of additive manufacturing
Shaping the future: recent advances of 3D printing in drug delivery and healthcare	Trenfield, S.J., Awad, A., Madla, C.M., Hatton, G.B., Firth, J., Goyanes,	2019	Healthcare and drug delivery	This review aims to discuss the state of the art of 3D printing technology in healthcare and drug delivery. Areas covered: The current and future applications of printing technologies within drug delivery and medicine have been discussed. The latest innovations in 3D printing of customized medical devices, drug-eluting implants, and printlets (3D-printed tablets) with a tailored dose, shape, size, and release characteristics have been covered.

	A., Gaisford, S., Basit, A.W.			
A review on additive manufacturing and its way into oil and gas industry	Sireesha, M., Lee, J., Kranthi Kiran, A.S., Babu, V.J., Kee, B.B.T., Ramakrishna, S.	2018	Oil and gas market	The oil and gas industry is poised to become one of the greatest sources of revenue generation across the world. The adaptation of scalable manufacturing technology, commonly known as additive manufacturing (AM) in the oil and gas industry, offers huge potential to transfigure the way high quality 3D objects are designed, manufactured and distributed. The adoption of AM technologies in this sector also allows a high degree of freedom of design and could exponentially reduce the time taken for the product to reach the market. In this arena, AM can be a method of producing lower volume and highly efficient intricate products with various materials like polymers, metals, ceramics and their composites
Guidelines for aircraft composite panels	Rusu, B., Blindu, S., Micu, A., Soare, V.	2020	Aerospace	The objective of this paper is to give a general perspective and present some elementary steps for manufacturing aircraft sandwich panel composites. Composite materials have been widely used in high performance sectors of the aerospace and there is considerable knowledge and confidence in their static, dynamic and crashworthiness properties.
Dental 3d-printing: Transferring art from laboratories to the clinics	Pillai, S., Upadhyay, A., Khayambashi, P., Farooq, I., Sabri, H., Tarar, M., Lee, K.T., Harb, I., Zhou, S., Wang, Y., Tran, S.D.	2021	Dentistry	3D printing is a versatile technique that allows the fabrication of fully auto-mated, tailor-made treatment plans, thereby delivering personalized dental devices and aids to the patients. It is highly efficient, reproducible, and provides fast and accurate results in an affordable manner.
State of the Art of Sustainability in 3D Food Printing	Otcu, G.B., Ramundo, L., Terzi, S.	2019	Food industry	3D Printing or Additive Manufacturing (AM) has become an emerging trend in global production area with a wide range of application fields. The increasing number of the concepts indicates the opportunity to address the needs and challenges of AM in both food industry and global scale. The technological, resource and industrial aspects of 3D Food Printing have the potentialities to enable to 'print' highly customized food, not just about the shape, but also about the structure, texture, flavour, **taste**, nutritional value, new edible alternatives and specific formulations for different choices, where the individual meals become possible.
The impact of 3D Printing Technology on the supply chain: Manufacturing and legal perspectives	Chan, Hing Kai; Griffin, James; Lim, Jia Jia; Zeng, Fangli; Chiu, Anthony S. F.	2018	Business	The main purpose of this research is to uncover the obstacles that resist mass-scale applications of 3DP. By means of empirical semi-structured interviews with 3DP companies in China, it is found that many companies can see the benefits of 3DP, but its potential has not been delivered as promised.

3D Bioprinting Stem Cell Derived Tissues	Tasnim, Nishat; De la Vega, Laura; Kumar, Shweta Anil; Abelseth, Laila; Alonzo, Matthew; Amereh, Meitham; Joddar, Binata; Willerth, Stephanie M.	2018	Biomedical industry	First, we cover 3D printing technologies and discuss the different types of stem cells used for tissue engineering applications. We then detail the properties required for the bioinks used when printing viable tissues from stem cells. We give relevant examples of such bioprinted tissues, including adipose tissue, blood vessels, bone, cardiac tissue, cartilage, heart valves, liver, muscle, neural tissue, and pancreas. Finally, we provide future directions for improving the current technologies, along with areas of focus for future work to translate these exciting technologies into clinical applications.
Envisioning the era of 3D printing: a conceptual model for the fashion industry	Sun, Lushan; Zhao, Li	2017	Fashion industry	The purpose of this conceptual study is to examine the potential impacts and challenges of integrating Direct Digital Manufacturing methods, specifically 3D printing (3DP), in the fashion industry. To recognize and organize such integration, we first examine the nature of Direct digital manufacturing (DDM) in contrast to traditional manufacturing approaches. After that, a conceptual model applied to DDM integrated fashion industry was then proposed to address this change
Research Progress on 3D Printed Graphene Materials Synthesis Technology and Its Application in Energy Storage Field	Wang Nan; Yan Shao-jiu; Peng Si-kan; Chen Xiang; Dai Sheng-ling	2017	Technology and energy sector	In this paper, the progress of 3D printed graphene materials synthesis technology and its application in energy storage field were reviewed. The viscosity and printability of graphene ink are key factors for realizing graphene 3D printing. Scalable preparation of graphene ink with facile process, controllable concentration and additive free will be the research focus of graphene 3D printing technologies in the future. The integrated printing of graphene energy storage devices such as graphene supercapacitor, lithium sulfur battery and lithium-ion battery is the development direction in this area.
A Systematic Review of Digital Technology Adoption in Off-Site Construction: Current Status and Future Direction	Wang, Mudan; Wang, Cynthia Changxin; Sepasgozar, Samad; Zlatanova, Sisi	2020	Construction sector	This paper intends to evaluate the current literature of digital technology applications in OSC. Scientometric analyses and a systematic review were carried out evaluating fifteen typical digital technologies adopted by OSC projects, including building information modelling (BIM), radio frequency identification devices (RFID), global positioning systems (GPS), the Internet of Things (IoT), geographic information systems (GIS), sensors, augmented reality (AR), virtual reality (VR), photogrammetry, laser scanning, artificial intelligence (AI), 3D printing, robotics, big data, and blockchain. This review formulates a clear picture of the current practice of these digital technologies and summarizes the main area of application and limitations of each technology when utilized in OSC.

towards Industry 4.0				
Valuing Value-Based Pricing	Bloomenthal, A.	2020	Feasibility assessment	Value-based pricing is a strategy of setting prices primarily based on a consumer's perceived value of a product or service. Value pricing is customer-focused pricing, meaning companies base their pricing on how much the customer believes a product is worth.
Material P design guide	Confidential	-	Properties material P	This design guide intends to explain the usage of the material P. Based on specific properties of the material the necessary treatment is substantiated.
Material T design guide	Confidential	-	Properties material T	This design guide intends to explain the usage of the material T. Based on specific properties of the material the necessary treatment is substantiated.
Additive Manufacturing and Its Impact on the Supply Chain	Zijn, H. Knofius, N. Van der Heijden, M.	2018	Impact on supply chain	
Porter's 5 Forces	Scott, G.	2020	Five forces model	Porter's Five Forces is a model that identifies and analyses five competitive forces that shape every industry and helps determine an industry's weaknesses and strengths. Five Forces analysis is frequently used to identify an industry's structure to determine corporate strategy. Porter's model can be applied to any segment of the economy to understand the level of competition within the industry and enhance a company's long-term profitability.
Overview advantages and disadvantages several production methods	Custompart	n.d.	Production methods	This source contains important information about specific production methods and is used to compare the applied methods to materials P and T.
Due to confidentiality, other used sources cannot be presented				

3.6 Integration of theory

The following sources can be identified as appropriate sources for the thesis:

- Healthcare and drug delivery (Trenfield, S.J., et al.,2019)
- Oil and gas market (Sireesha, M., et al., 2018)
- Aerospace (Rusu, B., et al.,2020)
- Dentistry (Pillai, S., et al., 2021)
- Food industry (Otcu, G.B., et al.,2019)
- Business (Chan, H.K., et al.,2018)
- Biomedical industry (Tasnim, N., et al.,2018)
- Fashion industry (Sun, L., et al.,2017)
- Technology and energy sector (Wang N., et al.,2017)
- Construction sector (Wang, M., et al,2020)
- Valuing Value-Based pricing (Bloomenthal, A.,2020)
- Material P design-guide (confidential, -)
- Material T design-guide (confidential, -)
- Additive Manufacturing and Its Impact on the Supply Chain (Zijm, H., et. al.,2018)
- Porter's Five Forces (Scott, G.,2020)
- Overview advantages and disadvantages several production methods (Custompart, n.d.)

4 Solution design

In this chapter I will explain the methodology that underlies the thesis. For all the research questions there is a methodology formulated, these combined will form all the input necessary to answer the main research question. First, I will cover the methodology per research question, to indicate how each research question plays its role to the main research question. Then, I will explain how the main research question is answered, in the form of the feasibility case. Again, the answered research questions can be considered as the input for the answering of the main research question, the feasibility case.

4.1 Methodology per research question

- ***"What would be the initial investment in hardware changes to the current machinery to be compatible with material T?"***

The approach in answering the research question will consist of two semi-structured interviews, one with the CTO of company X, the other with the head of the process department of company X.

In the conducted semi-structured interviews with both participants of company X, the following asked questions will contribute to answering the research question:

1. **Is there a specific component of the machinery that needs to be changed, to be able to process material T?**

2a. If answer to question 1 is "Yes": Which component should be changed?

2b. If answer to question 1 is "No": Why is this statement valid, that the hardware now is good enough?

3. In what do you see the biggest challenges considering the adoption of material T?

Afterwards, I will connect the costs to the indicated changes that have to be made to the hardware. This will form the conclusion of this research question.

- ***"What would be the initial investment in process development to the current machinery to be compatible with material T"***

The approach of answering the research question will consist of three semi-structured interviews, one with the CTO of company X, one with the head of the process department, and one with the head of the system department.

In the conducted semi-structured interviews with the three participants of company X, the following asked questions will contribute to answering the research question:

1. What exact buckets can be scaled under the heading "Process development", in general?

2. What could be other costs to incorporate in the process development for material T?

3. How do hardware development and process development relate to each other?

4. Is the process development of material T comparable with the process development of material P?

5a) If answer to 4 is yes: What is the approximated FTE's to be invested in the earlier mentioned buckets?

5b) If answer to 4 is no: What would the process development of material T look like and what are the approximated FTE's to be invested per allocated bucket?

Through these questions, I will be able to identify the buckets that will play part in the process development of material T, via this way I will validate my earlier information documentation section about the buckets. After the confirmation and possible addition of other buckets, I will gain more in-depth knowledge about the reason that material T can or cannot be compared with material P. To conclude in the end with an approximation of the approximated invested FTEs per allocated bucket. For the exact costs of an FTE invested in the process development I will consult the CFO of company X that can give me the exact quantifications for that.

- ***"What are material T's current applications and what value can company X add here that is unique?"***

I will answer this research question via the following approach:

First, I will map the current competitors in the market via the following selection criteria:

- The company is active in more sectors than only the electronic sector
- The company must use either additive manufacturing or traditional methods to process material T
- The company works upon request of the customer, not only production of standard parts
- The company must be findable online, through relevant search criteria
- The company must produce end-products, not semi-finished products

Then, I will map the current applications that fulfil these criteria for material T. Finally, I will explain the two-fold approach of how company X can add unique value to the market of material T, (i) the benefits of additive manufacturing on the current applications and (ii) through outside-of-the-box ideas for applications, where additive manufacturing brings unique benefits.

Afterwards, I will elaborate on the currently used applications for material T and summarize the way company X can add value to the market of material T.

1. Competitor search

The goal of this competitor search is mainly to find out the following:

- Are there companies that can process material T?
- Is material T widely used by producers of parts?
- How strong are the competitors?

This competitor search will be done via internet research. The competitors will be mapped in a document where some additional interesting information is added, to give a clearer picture of their role in the market of material T.

2. Mapping of current applications

The scope that will be used to map the current applications of material T will be done based on the sketched landscape in the introduction section. The derivation that can be made from these sections for the scope is the following:

- The part made for a certain application must be an end-product
- The part must be made through the traditional methods, either injection/compression molding or machining

Based on these criteria, the applications found via internet research will be mapped per sector. Also, there will be explained why material Tis suitable for these types of applications.

3. **Unique addition of value**

The added value that company X could bring to the market is approached in two ways. First, through what company X's 3D printing can add to the current sketched applications. And second, outside-of-the-box ideas where 3D printing has unique added value.

- Lower waste
- High complexity of parts
- Rapid prototyping

These advantages of 3D printing are some examples which should come forward out of the added value. Then, based on the given advantages I will sketch applications that could be reached with the processing method of company X and gives advantages over the competition.

- ***"What is the estimated market potential of additive manufacturing material T for company X?"***

I will answer this research question via the following approach:

First, I will use internal data sheets that calculate the cost price of a pre-defined benchmark part for material P and material T. Then, based on value-based pricing the sell price of the benchmark part can be approximated for material P and material T. The difference between cost-price and sell price will give the margin on the benchmark part for three different order quantities, namely, one, ten, and thirty. This is done to cover both pricing ways of company X, which consist of order quantities under 5 and above 5. Based on the present margin for these instances, I will conclude on the profitability of this specific benchmark part and what this implies for the market potential.

4.2 Methodology on main research question

The assessment of feasibility, so answering the main research question, will be done upon the calculation of payback period for company X. This approach consists of weighing the perceived revenues from the material T benchmark part against the internal investment needed to get a material T compatible machinery, which consist of the hardware investment and process development investment.

This approach of combining the commercial case and technical case is it I will use to base the decision on the implementation of material T upon. It covers the internal investment and the perceived revenues from the benchmark part to calculate how long it will take company X to regain the investment made.

First, I will calculate how many parts need to be sold to regain the full investment, which is done by dividing the total internal investment of gaining material T compatible machinery by the margin per material T benchmark part. Then the outcome of this division is the number of benchmark parts that need to be produced for regaining this investment. I know that company X has eight equal printers, with a known operatable number of hours per week. Then, when it is known how much time it takes one printer to print one benchmark part, I can calculate how long it takes to print the number of parts to regain the full investment when R (.. to ..) printers are used for printing the benchmark part, which will be the final answer: the payback period on the initial investment if X printers are used. Based on the needed period, I will recommend to company X if this suggests a feasible implementation or not.

For this calculation of the payback period, there is assumed that all the produced parts will be sold for the value-based price.

5 Validity, reliability and limitations of research

Validity and reliability

Validity and reliability will be two of the more important parts when assessing my research. Company X has a unique processing method at hands, which is currently applied to material P. The uniqueness of this processing method has some implications concerning the measurability of my results in the external environment. I will not be able to find other instances that do the same type of processing, or it will be patented and therefore not freely available. I must fully rely on the reflection of my supervisor and the other stakeholders at company X. This singular approach could be quite a threat to validity and reliability. Though, through the approach I will take in my research, validity concerns will be minimized. Mostly, since the approach taken involves parties outside company X. On the supply side, I will have contact with supplier B, the party that will help company X with the supply of material T. Adding their perspective and expertise to my research will help in validating the result I gather within company X. On the demand side, I will define a benchmark part in which profitability will be tested. This way I can get a feeling of the market environment of material T.

Scope and limitations

With regards to the technical case, it is out of scope to cover the most technical aspects of the parts out of which the machinery is build up. With my IEM background I lack certain knowledge on in-depth technical part, therefore I will only focus on the costs that are brought with some changes to the machinery to make it compatible with material T. Possibilities like redesigning parts or changing the position of certain parts are not covered in this research.

With regards to the commercial case, in the beginning I will decide upon a benchmark part. In all the other upcoming questions, there will only be made use of this benchmark part. It is out of scope for my research to cover other possible scenarios or benchmark parts, mainly due to the lack of time to get a full-fledged result. Also, in the commercial case, one of the limitations is that the estimates of the sell price for the benchmark part are conceptual due to the value-based pricing principle that is applied. The approach of setting the price on what it is worth for the customer may bring some uncertainty.

For material T is still quite unknown how this material could be a replacement or a better alternative for the current applications of plastics or metals. I have the opportunity to talk with the possible supplier of the raw material for company X, but that is only one part of the costs of producing the benchmark part. The other parts of development and other possible errors that will form the other part of the costs when producing are hard to be estimated, since material T is not being printed yet. Due to the confidential nature, there is not much information present about printing material T. Therefore, comparing will be hard and some assumptions must be made about uncertainties. What these assumptions will be, will be decided with my supervisor, to make sure they are realistic.

More generally, the implementation of material T will be still quite conceptual for company X. At the moment they are searching for the greater use cases of this material, if the use cases are absent, then the added value of the implementation is also not there, since there is no money to be made. This specific point could be a limitation of my research, since the search for specific use cases could be harder than expected which implies less accurate results on the commercial case.

Also, the development of the currently used material P, is continuing as well. So, to which extent the result of the research will be completely implemented is the question. It is a moment where the technology is there, but the market is running behind on the innovation. This could be a limitation in my research, since certain outcomes of my research will not have the impact, I would like to see.

6 Conclusion of thesis

Through the approach I used it was able to combine both outcomes of the commercial case and the technical case into an overall conclusion. I do this via the calculation of the payback period for company X on the implementation of material T. The period it will take company X to regain the investment diverges from ….. days to ….. days, dependent upon the number of printers are set available to print material T benchmark parts. In this conclusion it is assumed that all parts are sold.

In the current situation, where company X does not set the implementation of material T as the highest priority, it will be unlikely that all printers will be allocated to the production of material T parts. As an appropriate number of used printers, I advise the use of …. printers. This way company X can still develop their capabilities with material P on …. printers and the payback period is less than … years. In the case where three printers are used, it will cost company X ….. as initial investment and it will take …. working days to reach the payback period.

I advise company to start the implementation of material T based on the following parts of my research:

- The total development period to get material T compatible machinery is foreseeable
- Due to the already gained knowledge about processing material P, the development for material T will take less time
- A completely new market can be entered and company X will be able to bring their unique addition of value to it
- The substantiation does confirm added value of material T in a benchmark part
- The amount of time to regain the investment will be …. working days, if .. printers are used

7 Recommendations to company X

Based on the findings in my research I would like to explain some opportunities to investigate further for company X.

First, I would recommend company X to dedicate more specific research to the search for material T applications per sector. From my research, several applications can be derived, but more in-depth research on this would give company X a much more accurate picture of the total material T market. I would suggest focussing mostly on the sectors that have a proven demand. Also, I would suggest arranging meetings with potential clients to gain more insight into what they would like to see in material T products. From this experience, company X will be able to give more concrete options to clients that need a specific part for their problem.

Second, the assessment of the market potential of additive manufacturing material T for company X could be more complete. As a follow-up on the currently done work on the benchmark part, the manifold, I would suggest approximating the number of sales for this specific part. This way company X will gain more insight in how lucrative it will be to produce such a manifold.

Third, there is no historical data on the material T produced parts, obviously since company X is not able to 3D print this material yet. This implies that the sales approximation could be done via (combining) one of the following advised approaches:

- Approximating the number of sales for material T based on the historical data of material P
- Mapping the current size of the material T market and estimate the percentage that company X can claim of the market

Fourth, I would recommend using more benchmark parts, than just this manifold, where each individual part represents another focus. For example, one part for one different applicable sector where demand is proven.

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Due to confidentiality, this reference list is not complete compared to the full thesis.