FACTORS INFLUENCING THE ADOPTION DECISION OF METAL ADDITIVE MANUFACTURING TECHNOLOGIES

L.J.E. Nollet

S1129120

FACULTY OF BEHAVIOURAL MANAGEMENT AND SOCIAL SCIENCES

MASTER BUSINESS ADMINISTRATION

EXAMINATION COMMITTEE

Prof. Dr. Ir. J. Henseler

Dr. A.H. (Rik) van Reekum

Onno Ponfoort

DATE

24-08-2017

Abstract

A common problem for many organisations is how to increase the rate of diffusion of an innovation. According to Rogers(2003), the innovation adoption decision is a highly complex process at firm level, as this involves a number of individuals whom all play a role in the buying process. Nonetheless, the influence of individuals is inadequately addressed in most alike adoption studies at firm level. As our research builds on contemporary adoption theory, we utilise the technology-organisation-environment framework from Tornatzky et al.(1990) for this research and include the role of individuals as stressed by organisational buying behaviour literature. Furthermore, the adoption of metal additive manufacturing seems to be difficult for many companies, despite the fact that there is a wide variety of application possibilities. Therefore, it is essential to understand the main factors for the adoption of Additive Manufacturing (AM) technologies. The following research question is proposed accordingly:'Which factors influence the decision of potential customers whether or not to adopt metal additive manufacturing technologies in the Dutch manufacturing industry?' A qualitative research approach was used, including sixteen semi-structured in-depth interviews at both adopting and non-adopting companies of metal AM systems. Only companies that considered to invest in a metal AM system were included in the research sample. Insight was provided by analysing 19 factors within the technological, organisational and environmental context. For adopters, we found that relative advantage, trialability, centralisation, champion, pressure from business partners and supplier marketing activities were stressed as important factors which positively influence the adoption decision of metal AM. In addition, the double role of the decider and the champion positively affected the adoption decision as well. For non-adopters, we found that trialability, observability, financial costs, centralisation, pressure from business partners and pressure from competition negatively influenced the adoption decision.

1. Introduction

A common problem for many organisations is how to increase the rate of diffusion of an innovation. According to Rogers(2003), the innovation adoption decision is a highly complex process at firm level, as this involves a number of individuals whom all play a role in the buying process. Nonetheless, the influence of individuals is inadequately addressed in most alike adoption studies at firm level. No theories were found that describe the interrelation between the adoption of technological innovations at firm level and the role of individualsin the buying process as stressed by organisational buyingliterature.

The Diffusion of Innovation (DOI) model (Rogers, 2003) and Technology-Organisation-Environment (TOE) framework (Tornatzky et al., 1990) describe the adoption decision process at firm level (Oliveira & Martins, 2011). DOI is based on a meta-analysis, currently including thousands of innovation studies and has consistent and substantial empirical support.Although Rogers explains the fundamental principles of innovation processes in his book *Diffusion of Innovations*, it received criticism because it does not address environmental factors sufficientlywhen explaining the adoption decision process (Oliveira & Martins, 2011). These environmental factors relate to the arena in which the organisation operates, such as the market structure and governmental regulations and are of different nature between various environments. The TOE framework,however,complements to Rogers' DOI model by also including environmental influences.The relevance of the environmental context in addition to the technological and organisational context has been acknowledged by numerous researchers (Chong, Ooi, Lin, & Raman, 2009; Frambach & Schillewaert, 2002; Thong, 1999; Waarts, Van Everdingen, & Van Hillegersberg, 2002; Y. M. Wang, Wang, & Yang, 2010).The TOE-framework is used to explain the adoption decision in multiple industries, including manufacturing(Mishra, Konana, & Barua, 2007; Zhu, Kraemer, & Xu, 2003)and has been tested worldwide (Zhu, Kraemer, & Xu, 2006).Similar to DOI, it has a solid theoretical basis and consistent empirical support (Oliveira & Martins, 2011). As our research builds on contemporary adoption theory, we utilise the technology-organisation-environment framework for this research. Although both adoption theories discuss the role of individuals, they do not address this sufficiently in their models. Hence,the buying roles as stressed by organisational buying behaviour literature is included in this research, as this has great similarities with the adoption theories and also includes the role of individuals.

Organisational buying behaviour refersto the process by which organisations perceive a problem, establish the need for purchasing products and identify, evaluate and choose among multiple brands and supplier to solve this problem(Johnston & Lewin, 1996).Just like adoption theories, organisational buying theories gain insight into buying processes of organisations. These theories differ on two main aspects. First, unlike adoption theories, organisational buying theories do not exclusively focus on buying technological innovations and mainly include purchasing low complex products in large volumes. This might be the main reason why organisational buying theories currently have not been combined with adoption theories in analysing the adoption of highly complex technological innovations. Second, in contrast to the TOE framework, the three original organisational buying behaviour theories from Robinson, Faris and Wind (1967)**,** Webster and Wind (1972) and Sheth (1973) do emphasise the role of individuals in the organisational buying process. Because the importance of individuals is emphasised in adoption theories as well, though not sufficiently addressed, it is assumed that including the role of individualsin combination with the TOE framework, might providea better understanding into the main drivers for the adoption of a technological innovation. Our research fills this gap. Therefore, this research aims to extend the TOE framework from Tornatzky et al.(1990), by also including the role of individuals as stressed by organisational buying theories. The following research question is proposed accordingly; *"Which factors influence the decision of potential customers whether or not to adopt metal additive manufacturing technologies in the Dutch manufacturing industry?"*

Many authors explain the adoption of technological innovations. However, few adoption studies focus on the adoption of Digital Manufacturing (DM) technologies (Oliveira & Martins, 2011). In comparison with other adoptions studies (e.g. Information Technology), factors explaining whether or not to adopt the innovation are likely to differ for DM technologies. For instance, these factorsmight relate to the visibility of the innovation or the ability to try out the innovation. Examples of such novel DM technologies are Additive Manufacturing (AM) technologies. AM, also known as 3D Printing (3DP), is a collective name for several technologies which uses layer-upon-layer production to create a three-dimensional object (ASTM International, 2013). AM first emerged in the early 1980s, but only recently the popularity of AM increased and the market is expected to grow at a fast pace (Kietzmann, Pitt, & Berthon, 2015; SmarTech Markets Publishing LLC, 2017; Wohlers & Caffrey, 2016).

Whereas AM initially was used as a way of prototyping, currently a number of promising final product fabrication applications exist (Berman, 2012; Harris, 2011; Huang, Leu, Mazumder, & Donmez, 2015; Kianian, Tavassoli, Larsson, & Diegel, 2015; Rayna & Striukova, 2016; Wohlers & Caffrey, 2016).Multiple case studies prove that AM is in some cases a better production method than conventional production technologies. For instance, the entire hearing aids industry utilisesAM technologies (Richard D'Aveni, 2015). Also, the aerospace industry uses strong light-weight parts, which can only be produced using AM technologies (Industrial Laser Solutions Editors, 2016).Despite the fact that there is a wide variety of application possibilities, the adoption of AM seems to be difficult for many companies (PwC & Manufacturing Institute, 2016; Rayna & Striukova, 2016; Wohlers & Caffrey, 2016). It is commonly suggested that AMtechnologies can only be fully exploitedif, and when, AM is widely spread and used.Therefore, it is essentialto understand the mainfactors for the adoption of AM technologies.

According to multiple authors (e.g.Chau & Tam, 1997), research about innovation adoption decisions must be studied within appropriate contexts and with variables tailored to the specificity of the innovation.Therefore, we thoroughly analysed the wide variety of AM technologies. We found that metal AM is most interesting for theindustry, because it is one of the fastest growing and newest AM industries (Wohlers & Caffrey, 2016).Hence, the authors of this paper chose to focus on providing thorough understanding into the main drivers for adoption of metal AM technologies. In this research, adoption is defined as whether or not a company invests in a metal AM system. It is also assumed that environmental factors such as governmental regulations and market structure are of different nature between various countries. Thus, we limit our research to the Dutch manufacturing industry.

The paper is structured as follows: in the next section, the theoretical framework is discussed. We extensively examine the TOE framework from Tornatzky et al.(1990) by discussing 19factors that might influence the adoption decision on firm level. Also, the role of individuals as stressed by organisational buying behaviour theories are examined. The next section explains the research design in detail so that an accurate overview of the research procedure is provided. Hereafter, the results are presented. We end our paper with a discussion and conclusion, including the limitations of this research and suggestions for future research.

2. Theoretical framework

The literature review is divided into two parts. First, an extended version of the original TOE framework fromTornatzky et al. (1990) is thoroughly analysed, because it allows gaining insight into the adoption decision process at firm level. Second, the role of individuals as stressed by organisational buying behaviour literature is discussed. We aim to develop propositions on the interrelation between the TOE framework and the six buying roles as emphasised by organisational buying theories.

2.1 Extending the technology-organisation-environment framework

The TOE framework was developed to explain adoption decisions in three different elements of a firm's context. It represents how the technological, organisational and environmental context influences the adoption and implementation of technological innovation. First, the technological context is defined as the perceived characteristics of the technological innovation. Next, the organisational context refers to characteristics internal to the organisation, such as the skills and resources an organisation assumes it possesses. Finally, the environmental context relates to factors as a result of the arena in which the organisation operates, such as market structure and governmental regulations.

We thoroughly analysed multiple technological innovation-decision studies on firm level in order to gather information about the variety of constructs used. This resulted in an extended version of the original TOE framework by Tornatzky et al. (1990), as illustrated in figure 1. This framework will function as the basis for the research framework.

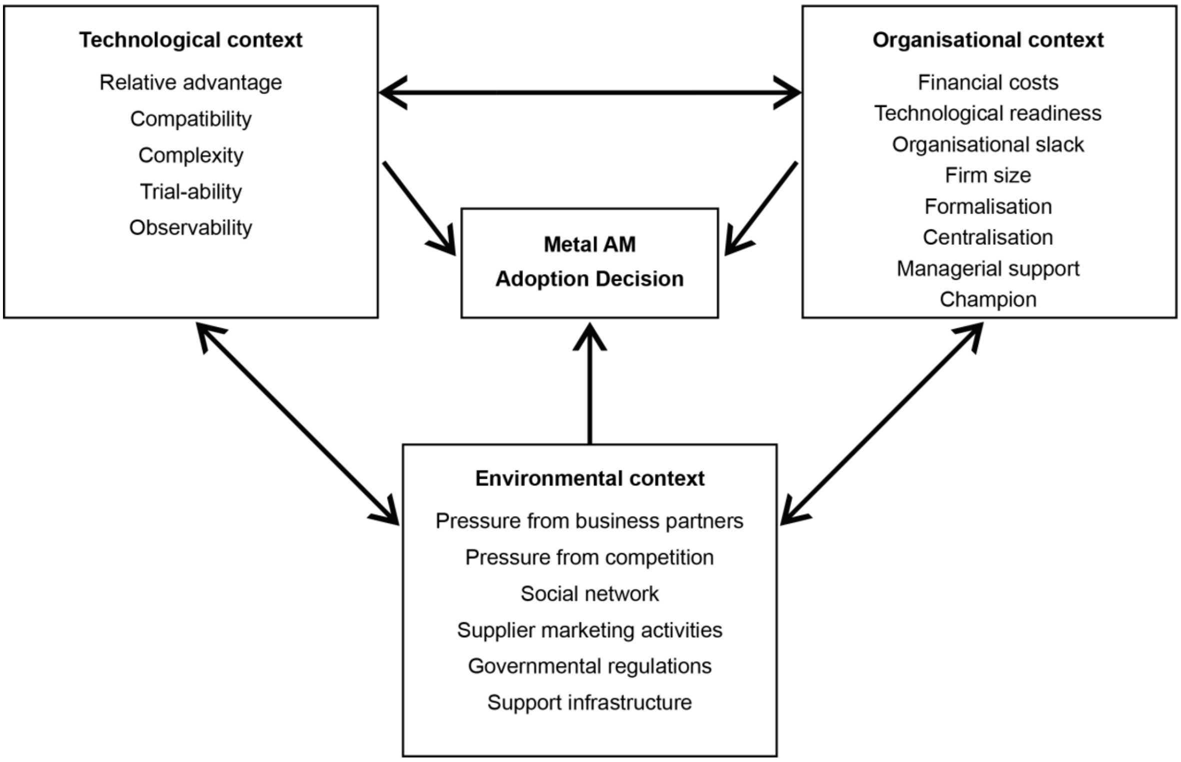

Figure 1: Technology-Organisation-Environment (TOE) framework

The next paragraphs extensively elaborate on the factors that are probable to influence the adoption decision on firm level. First, the technological context and its corresponding factors are discussed. Second, factors within the organisational context are covered. Finally, factors of the environmental context are addressed. We also aim to develop propositions on how these factors operate within the metal AM context.

2.1.1 Potential influence of factors within the technological context

Technological context is defined as the perceived characteristics relative to the technological innovation. It entails both the internal and external technologies relevant to the firm. This includes current practices and equipment internal to the firm, as well as the set of available technologies external to the firm. Tornatzky & Klein (1982) demonstrated that out of the five technological characteristics according to Rogers' DOI theory, relative advantage, compatibility and complexity have the greatest impact on the adoption decision at organisational level. However, the trialability and observability is expected to influence the adoption decision of metal AM as well. The five technological characteristics are discussed accordingly.

Relative advantage

Relative advantage refers to perceived benefits gained by the innovation relative to the idea it supersedes (Rogers, 2003). The impact on the adoption decision is acknowledged by multiple researchers (Chau & Tam, 1997; Talukder, 2012; Tornatzky & Klein, 1982). Kuan and Chau (2001) distinct two kinds of benefits, indirect and direct benefits. Direct benefits refer to operational savings related to increasing the internal efficiency of the organisation or product related benefits. Indirect benefits are strategical and competitive advantages that might impact either the business relationships and processes (Kuan & Chau, 2001).

For metal AM, there are many potential direct advantages, among which the ability to produce new shapes which cannot be produced with conventional production technologies. An improved organisational image isan example of an indirect advantage (Kuan & Chau, 2001).However, there is also a wide variety of potential disadvantages, which might influence the adoption decision negatively. Among these barriers are generic barriers as high costs for migration (Chau & Tam, 1997) and metal AM specific barriers like lack of reproducibility or material related barriers. Or in other words, the perception of hugely expensive or a limited amount of raw materials for metal AM might have a negative impact on the adoption of metal AM.

Compatibility

Compatibility is the congruence between the innovation with existing values, past experiences and the perceived need for improvement (Rogers, 2003). The more compatible an innovation is, the less uncertainty an adopting company is likely to experience. This is likely to influence the adoption decision positively (Frambach, 1993).

We distinguish two types of compatibility. First, Waarts et al (2002) suggest that a certain degree of fit with existing hardware and software in the organisation positively affects the adoption decision. Second, according to Mellor et al. (2014), for successful metal AM implementation it is important to have some degree of alignment between the technology and the business model. Therefore, both fit with existing hardware and software and business alignment are included in compatibility.

Complexity

Complexity is the degree to which an innovation is difficult to understand and use (Rogers, 2003). The more complex an innovation is perceived, the more skills and knowledge an organisation has to acquire in order to assimilate the innovation effectively (Rogers, 2003). Organisational learning theorystates that organisations may be viewed as a bundle of knowledge and skills related to their current operational and managerial processes (Nelson & Winter, 2009). Accordingly, the degree to which an innovation is perceived as difficult to understand and use varies between organisations.

Metal AM requires a new set of skills in order to fully exploit the potential benefits. Fewer design constraints in comparison with conventional production technologies allow new, previously impossible, geometries. Autodesk is heavily researching and investing in software developments that can generate such geometries. However, most of these software packages are relatively new and thus it is expected that this is not perceived as easy to use. The same goes for metal AM hardware as this technology is relatively new for theindustry. Nonetheless, closely related skills such as Computer-Aided Design (CAD) experience are likely to be present.

Trialability

Trialability refers to which degree an innovation can be experimented with on a limited basis (Rogers, 2003). Innovations that can be tried out are adopted and implemented more rapidly and more frequently than less triable innovations (Rogers, 2003).

With respect to metal AM, two types of trialability are distinguished. First, in line with other researchers, trialabilityrefers to an individuals' perception about the extent to which suppliers offer the possibility to try out metal AM technologies (Frambach, 1993). Second, previous experiences with other forms of AMtechnologies might foster the adoption of metal AM. Metal AM is relatively expensive in comparison with plastic AM technologies. Although plastic AM technologies have completely different characteristics and application possibilities, trying out such 3D printers on beforehand, might cause a feeling of habituation and thus function as a stepping stone for the adoption of metal AM.

Observability

Observability is the degree to which the outcomes of an innovation are visible and communicable to others (Rogers, 2003). This includes defining the business case as justification for a proposed investment on the basis of its expected return on investment. It also includes the idea of the innovation being visible (Moore & Benbasat, 1991). The visibility of the results of an innovation is likely to positively influence the adoption rate.According to Rogers(2003), a technological innovation is usually composed of two parts: software and hardware. Hardware "embodies the technology as material or physical objects" and software is "the information base for the tool" (Rogers, 2003, p. 12). He states that software innovations are less observable and therefore usually have slower adoption rates than hardware innovations.

Both, the physical and software component are very important with respect to AM. In comparison with software based technological innovations (e.g. Enterprise Resource Planning systems), metal AM can mainly be classified as hardware. The visibility of metal AM technologies at fairs, conferences or within the social network is likely to raise the awareness and thus influence the adoption decision. Also, because metal AM is a manufacturing technology, it is expected that defining the business cases is expected to play a role in the adoption decision process.

2.1.2 Potential influence of factors within the organisational context

Organisational context refers to characteristics internal to the organisation such as scope, size and managerial structure. In specific, it is defined as perceived organisational resources (Kuan & Chau, 2001). Although it is important that an organisation perceives the technological innovation as valuable, it must also possess the resources to exploit those benefits. If an innovation cannot be exploited due to a lack of resources, adoption is pointless. A well-structured firm can foster the adoption of an innovation. Baker (2012) highlights the case of motorcycle-maker Harley-Davidson Motor Company, in which the organisational context was exceptionally well-structured to foster the adoption of innovations. The following paragraphs explain different organisational characteristics that might influence the propensity to adopt metal AM. These factors are derived from several adoption studies and include the following: financial costs, technological readiness, organisational slack, firm size, formalisation, centralisation, managerial support and champion.

Financial costs

Financial costs is one of the major organisational factors influencing adoption decision(van Everdingen, van Hillegersberg, & Waarts, 2000). Financial costs are defined as the perceived financial costs as a result of considering purchasing or purchasing metal AM. This might include both, recurrent and non-recurrent costs such as operating and set-up costs (Elbertsen & Reekum, 2008).

As the costs of metal AM machines and material are considerable ($100.000-$2 million non-recurrent costs), it is likely to influence the adoption decision. Also, raw material is significantly more expensive for metal AM than for conventional production technologies (Thomas & Gilbert, 2014) and commonly recognised as one of the main hurdles for the adoption of metal AM.

Technological readiness

Technological readiness is often defined as the know-how an organisation assumes it obtains. The influence of technological readiness is acknowledged by multiple authors (Chau & Tam, 1997; Elbertsen & Reekum, 2008; Iacovou, Benbasat, & Dexter, 1995; Kai-ming Au & Enderwick, 2000; Kuan & Chau, 2001). Lack of knowledge could negatively impact the adoption decision as it creates a knowledge barrier. According to Attewell (1992), firms suspend the decision to adopt complex technological innovations until they possess sufficient technological capability for successful implementation. Lack of technological know-how is acknowledged as one of the major metal AM adoption barriers (Gao et al., 2015; PwC & Manufacturing Institute, 2016).

Organisational slack

Organisational slack is defined as the pool of overcapacity to produce a given level of organisational output (Nohria & Gulati, 1996). It is one of the most frequently discussed factors influencing the decision to adopt. In financial terms, slack is frequently regarded as retained profits or savings. Also, overcapacity of other resources such as human resources or time goes by the term slack. Tornatzky et al. (1990) state that slack is desirable and beneficial, but not essential nor sufficient for innovation to take place. Adoption of innovations can occur in absence of this factor.

Firm size

Firm size is also commonly discussed in innovation studies. However, no indisputable link between this factor and innovation has been established. It seems logical that larger firms are more likely to adopt innovations, because they possess a higher level of resources (Iacovou et al., 1995). Bigger organisations are more probable to benefit from economies of scale, more capable of bearing high risks and generally possess more power to urge business partners to adopt the technological innovation as well (Tornatzky et al., 1990). However, this factor has received criticism because it might be the origin of underlying organisational resources such as organisational slack.

Formalisation

Formalisation is referred to as the organisational regulations in which procedures are fixed (Frambach, 1993). These include the recording of job tasks and responsibilities, quality norms and other regulations. Damanpour (1991) suggests that flexibility and low emphasis on work rules facilitate the adoption of innovations, while high formalisation is beneficial for the implementation of new innovations.

Quality certification and other norms are standard in the manufacturing industry. Metal AM allows the production of new geometries. In the aerospace industry, these new geometries are utilised to create strong and light-weight parts. Especially for flight-critical components, qualification and certification efforts are necessary. New materials and material characteristics must be thoroughly tested before they can be used (Seifi, Salem, Beuth, Harrysson, & Lewandowski, 2016). Quality certification is acknowledged as one of the major adoption barriers of AM technologies (Frazier, 2014; Huang et al., 2015; Seifi et al., 2016; Simonot, Cassaignau, & Coré-Baillais, 2015; Vartanian & McDonald, 2016).

Centralisation

Centralisation is defined as the perceived amount of power and control in the hands of relatively few individuals (Rogers, 2003). Decentralised organisational structures are associated with adoption. Such organisations are characterised by the emphasises on working in teams, ahigh degree of responsibility and promotion of individual communication (Baker, 2012). It is probable to positively influence the decision to adopt(Attewell, 1992). On the other hand, centralised organisational structures are acknowledged to foster successful implementation (Baker, 2012; Damanpour, 1991).

Managerial support

Managerial support is the degree to which top management supports the adoption and use of metal AM in the firm's operations (Lewis, Agarwal, & Sambamurthy, 2003a; Premkumar & Ramamurthy, 1995). Creating an accommodating and supporting organisational context can foster innovation (Tushman & Nadler, 1986). This includes financial commitment, encouragement from top management and rewarding innovation formally and informally. Chong et al. (2009) state that top management support is essential to adopt a technological innovation successfully.

Champion

The champion refers to the existence of a single person, highly enthusiastic and committed to introducing metal AM in the organisation (Premkumar & Ramamurthy, 1995). Multiple authors state that a champion is instrumental in the adoption of technological innovations (Baker, 2012; Grover, 1993). Grover (1993) also highlights the role of the champion in achieving successful implementation.

2.1.3 Potential influence of factors within the environmental context

The environmental context is the domain in which a firm conducts its business (Tornatzky et al., 1990). It allows the TOE framework to be able to better explain intra-firm innovation diffusion (Hsu, Kraemer, & Dunkle, 2006). For instance, Kuan and Chau (2001) point out that in many cases the adoption of a technological innovation is mainly based on influences exerted by business partners or competitors. They even state that the decision to adopt in some case has nothing to do with the technological or organisational context. The environmental context includes the structure of the industry, regulatory environment, and the presence or absence of service providers (Baker, 2012). It offers both constraints and opportunities for the adoption of technological innovations. The next section explains six environmental factors, based on innovation studies from multiple authors (Baker, 2012; Chau & Tam, 1997; Elbertsen & Reekum, 2008; Frambach, 1993; Kuan & Chau, 2001; Mellor et al., 2014; Tornatzky et al., 1990). These factors are pressure from business partners, pressure from competition, social network, supplier marketing activities, government regulations and support infrastructure.

Pressure from business partners

Pressure from business partners relates to pressure from both, customers and suppliers to invest in a technological innovation. Kuan and Chau (2001) argued that a firm might perceive pressure from business partners to adopt a technological innovation. Especially the role of firms high up in the value chain are emphasised. These firms have a lot of power and can influence other partners to innovate. Furthermore, pressure from business partners also includes the propensity a client's or supplier's interest in the technological innovation. This might trigger the organisation to adopt the innovation for strategical reasons.

Pressure from competition

Pressure from competition is defined as the degree to which an organisation perceives pressure from competition. Frambach (1993) highlights the importance of the perception of market competition. He states that the pressure to innovate is higher when employees in the industry perceive intense competition. Likewise, Baker (2012) mentions that intense competition stimulates the adoption of innovation.

Social network

Social network refers to the degree to which an organisation interacts with members of a social network (Frambach & Schillewaert, 2002). Rogers (2003) relates to this as the degree of interconnectedness, which is defined as information sharing between organisations. This involves interaction on both, personal and commercial basis (Frambach, 1993).

Social network influences can take place in several ways. First, Frambach and Schillewaert (2002) note that the function of a social network is to reduce ambiguities concerning the innovation. The adoption of metal AM is in its early stage and technological developments proceed at high pace.

Therefore, organisations are likely to perceive a lot of uncertainty regarding the way metal AM will function in an organisation. The social network functions as a means to reduce uncertainty. Second, a social network may also increase the value of an innovation through network effects. A network effect is present when the value of a product increases as the number of users expands as well. To give an illustration, the value of a telephone is dependent on the amount of users. The value of metal AM, however,is not dependent on the amount of users using it like the value of a telephone. Nonetheless, a high amount of users increases the awareness throughout the whole value chain and allows to fully exploit the potential benefits of metal AM technologies. Also, an increased amount of metal AM users may raise awareness and foster the development of metal AM.

Supplier marketing activities

Supplier marketing activities focus on the supply side of the market instead of the demand side. These activities also stimulate the decision to adopt positively (Frambach & Schillewaert, 2002; Gatignon & Robertson, 1989; Waarts et al., 2002). Simply put, active suppliers will increase awareness among customers, which will lead to more customers considering investing in an innovation (Elbertsen & Reekum, 2008; Waarts et al., 2002). Brancheau and Wetherbe (1990) found that early adopters are more exposed to both, mass media and interpersonal communication channels and are more active in seeking information than later adopters.

Governmental regulations

Government regulations refer to policies which either encourage or discourage the decision to adopt an innovation (Baker, 2012). Legislation might obligate or discourage organisations to adopt an innovation. Funding regulations, on the other hand, is an example of a governmental regulation which might positively influence the adoption decision.

Support infrastructure

Support infrastructure is defined as the availability of skilled labour, proficient consultancy, research facilities, service providers, and other technology suppliers (Baker, 2012). The support infrastructure for technological innovationsis likely to influence the decision to adopt. According to Baker (2012), a proper supportive infrastructure fosters the diffusion of innovations.

Currently, the Netherlands contains several 3D print service providers (e.g. Oceanz and Shapeways). These service providers are likely to influence a firm's decision whether it is necessary to adopt metal AM or not. Firms might not want to take the risk of investing in metal AM equipment themselves, as the technology is relatively expensive and immature. Accordingly, a service provider might keep firms from adoption, because service providers allow utilisingmetal AM technology while avoiding the risks of investing in a relatively immature technology. On the contrary, it can also be argued in the opposite direction. A service provider or other metal AM suppliers may positively influence the propensity to adopt, because it might lead to spontaneous awareness as argued by Waarts et al. (2002). We also include the geographical location, derived from the AM implementation model of Mellor et al. (2014), as the geographical location relative to a technology supplier, service provider and so on might affect the adoption decision.

2.2 The interrelation between six buying roles and the TOE framework

Organisational buying behaviour theories refer to the process by which organisations perceive a problem, establish the need for purchasing products and identify, evaluate and choose among multiple brands and supplier to solve this problem. It is a set of complex events in which multiple persons are involved (Dimple, Turska. Sujata, 2015). An organisational buying behaviour model can help to identify the need for additional information. Particularly, it can help to specify targets, the kind of information requested for and help define the criteria that are likely to be used to make the purchase decisions (Johnston & Lewin, 1996). Organisational buying ranges from small and large quantities to highly complex machinery. However, it is mostly aimed at purchasing large volumes (Dimple, Turska. Sujata, 2015). For example, buying paper cups by McDonald's. Because the smallest part of organisational buying research considers high complex machinery, it is even more interesting to apply organisational buying theory to purchasing metal AM technologies.

The three original organisational buying behaviour models are developed by Robinson, Faris and Wind (1967)**,** Webster and Wind (1972) and Sheth (1973). These theories have substantial support after 25 years of empirical testing andare fundamentally similar(Johnston & Lewin, 1996). Organisational buying is often referred to as a group of several individuals which undertake different roles in the buying process. All three organisational buying theoriestake the influence of individual characteristics into account in order to describe the organisational buying process.The combination of individuals who participate in the buying process is defined as the buying centre, also referred to as the Decision-Making Unit (DMU).Individuals in the DMU may play one or more of the following buying roles: Decider, Gatekeeper, Influencer, Initiator, Purchaser and/or User.Webster and Wind (1972) argue that the DMU plays an important role in describing organisational buying behaviour. They state that every buying centre or DMU is unique due to the combination of various individual characteristics.Different educational backgrounds and experiences often generate substantially different goals (Sheth, 1973), making the adoption decision at firm level highly complex (Rogers, 2003).Nonetheless, the influence of the individuals in the DMU comes up short in the TOE framework. Hence, we aim to develop propositions to include the six distinct buying roles in the TOE framework. This paragraph examines the expected interrelation between each buying role and the TOE framework in the following order: Decider, Gatekeeper, Influencer, Initiator, Purchaser and User. The interrelations in figure 2 are based on the expected perceived influence of the three contexts in relation to the buying role.

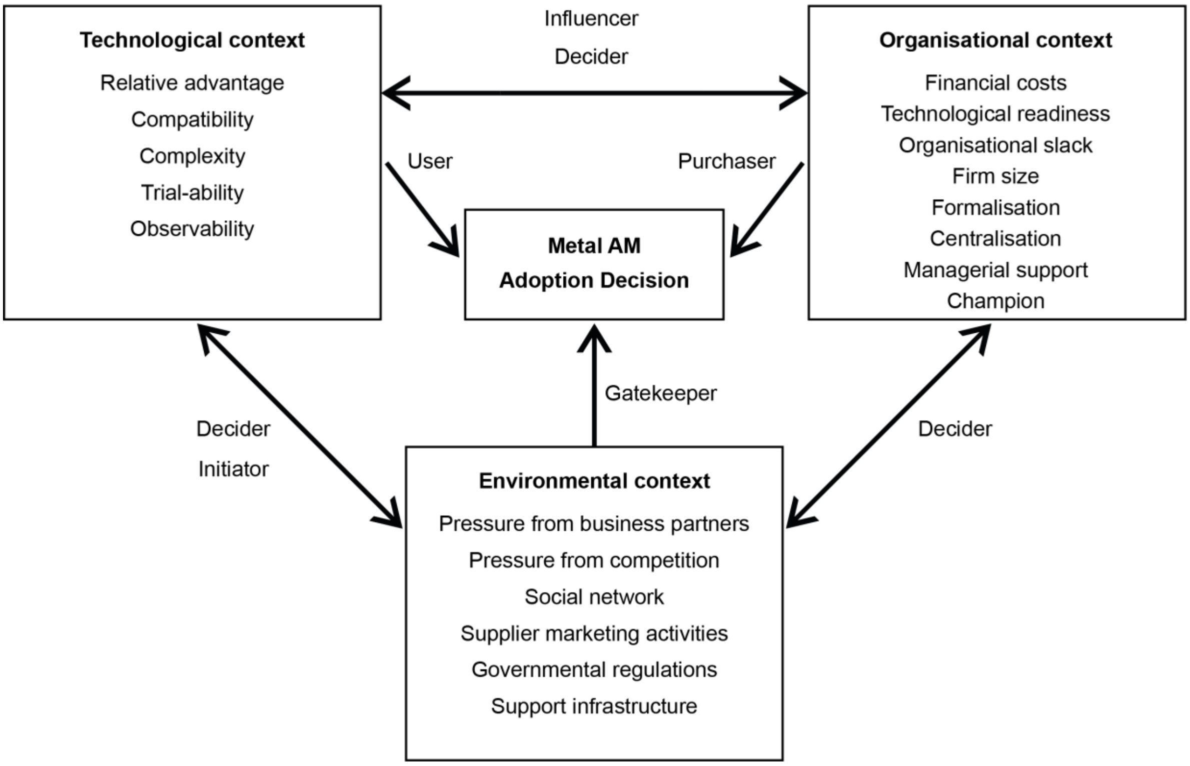

Figure 2: Interrelation between TOE framework and buying roles

First, the decider ultimately approves all or any part of the entire buying decision, whether to buy, what to buy, how to buy and where to buy(Webster &Wind, 1972). The decider is referred to as a member of top management (e.g. director) (Hammann, 1979). Top management is in charge of the organisation and ultimately responsible for all decisions made. One of top managements' main responsibilities is to sustain a competitive advantage and ensure the existence of the firm. This is mainly depending on the market developments from the sector in which the firm operates. It is likely that the deciders' propensity to invest is influenced by all the three contexts. Nonetheless, we expect that the deciders adoption decision is mainly driven by environmental factors. Because the decider possesses a lot of power, it is expected that this is one of the most important buying roles in the organisational buying process.

Second, the gatekeeper controls information or access to information (e.g. secretary) (Hammann, 1979; Webster &Wind, 1972). The gatekeeper is especially present in large firms with complex hierarchical structures. This role usually has a low position the hierarchy of the organisation and thus we expect that it has little influence on the adoption decision. Nonetheless, the influence of the gatekeeper must not be underestimated as it might control access to crucial information. It is expected that this role generally does not possess technological know-how, hence no relation with the technological context is expected. The gatekeeper, however, has a lot of contact with buyers, suppliers or others external to the organisation. Therefore, we expect that the gatekeeper is mainly influenced by environmental factors, such as supplier marketing activities.

Next, the influencer provides information for strategically evaluating alternatives(Webster &Wind, 1972). The influencer is often referred to as a consulting engineer. Influencers are associated with relatively much power and are usually part of top management(Hammann, 1979). The influencer comes up with alternative technological innovations and thus it is likely that its propensity to adopt is mainly influenced by factors related to the technological innovation. Additionally, we think that this role is influenced by organisational factors (e.g. centralisation) as well. Similar to the decider, we expect that this is one of the most important buying roles in the DMU.

Fourth, the initiator is the first person who identifies the need to buy a particular product of service to solve an organisational problem. It can be anyone within the organisation (e.g. director or production member) and is crucial as this role triggers the decision-making process. Because metal AM is highly complex machinery, we argue that the initiator is expected to have a technological background or technical interest at aminimum. Also, the initiator is likely to be influenced by environmental factors, as its environment might play a role in raising awareness about the technological innovation. Hence, we think that the initiator is mainly driven by technological and environmental factors.

Fifth, the purchaser holds the formal authority to select the supplier and to arrange the terms of condition(Webster &Wind, 1972).The purchaser is a member of the purchasing department (Hammann, 1979). The adoption decision of metal AM is a new buying task and is probable to have a major impact on the organisation. Therefore, it is expected that this buying role is often combined with one of the more influential buying roles (e.g. decider or influencer).

Finally, the user consumes or uses the product or service(Webster &Wind, 1972). The user is part of the production department(Hammann, 1979).Its propensity to adopt metal AM is expected to be mainly driven by the technological context, because users usually have a technological educational background.

Altogether, in section 2.1 the TOE-framework was thoroughly analysed by discussing a total of 19 factors that might influence the adoption decision at firm level, divided into the technological, organisational and environmental context. Subsequently, we aimed to develop propositions on the interrelation between the six buying roles, as stressed by organisational buying literature, and TOE-framework, which resulted in an extended version of the TOE-framework. It illustrates the expected perceived influence of the three contexts in relation to the buying role. This framework will function as the foundation for developing the research methodology.

3. Research methodology

This chapter utilises the theoretical framework from the previous section to develop the research methodology.First, the research design is discussed to provide insight into the research framework and substantiate the choice for a qualitative research approach. Second, the sample and participants are addressed by explaining the classification requirements. Next, the constructs are operationalised as preparation for the semi-structured in-depth interviews and analysis of the data. Finally, the data collection and analysis procedures are also covered to provide enough information to replicate the study.

3.1 Research design

This study aims to provide thorough understanding into the main drivers for the adoption of metal AM technologies. The TOE framework, illustrated in figure 1, is used as a basis for conducting semi-structured in-depth interviews. The buying roles of individuals are also included in the research design as presented in section 2.2 to gain more insight into the adoption process.

Two arguments are pointed out to substantiate the choice for a qualitative research. First, to the best of our knowledge currently no adoption studies at firm level attempted to research the influence of individuals. Therefore, this research aims to extend the TOE frameworkby studying the interrelation with six buying roles. Second, the research population is small, which makes it impossible to collect enough data for a reliable quantitative research.

3.2 Sample and participants

To provide a thorough understanding of factors influencing the decision whether or not to adopt metal AM technologies, both adopting and non-adopting companiesare unit of analysis.Non-adopting companies are included as well, because they can provide other important insights in the adoption process as there might be different patterns between both adopting and non-adopting companies. This research also intends to describe the differences between influencing the adoption decision for both categories. Therefore, both must be compared on an equal basis. Accordingly, the unit of analysis must meet the following classification requirements: (1) located in the Netherlands, (2) working in the manufacturing industry, and (3) must have considered to invest in a metal AM system.

Adoption research must be studied within appropriate contexts and with variables tailored to the specificity of the innovation (Chau & Tam, 1997). Between multiple countries, environmental factors such as market structure and governmental regulations are of different nature. Therefore, this research only includes firms operating in the Dutch manufacturing industry. Also, in order to compare on equal basis, both adopters and non-adopters must have been through the awareness stage of adopting metal AM. For adopters, we excluded companies that did not improve, change or extend their current organisation, because changing an acclimated business model is difficult to compare with creating a completely new business model. Also, non-profit organisations such as research institutes and universities were excluded as unit of analysis.

3.3 Operationalisation of the constructs within the TOE framework

Extensive desk research is conducted to operationalise the constructs of the TOE framework for two reasons. First, this is done as a preparation for the semi-structured in-depth interviews. Second, operationalising is required for the analysis of the data. The coding procedure of the data will be performed on the basis of the operationalised factors. This section covers all factors within the TOE framework as discussed in section 2.1. The operationalisation of the factors within the technological, organisational and environmental contexts are presented respectively in table 1, 2 and 3.

Technological context: operationalisation of the constructs

Technological context is defined as the perceived characteristics of the innovation. The operationalisation of relative advantage is discussed in more detail. The other factors are presented in table 1. Relative advantage is distinguished in direct and indirect benefits according to the operationalisation of the constructs by Kuan and Chau(2001). Metal AM is relatively immature and new for theindustry. Hence, there are many disadvantages of metal AM. For instance, expensive raw material, limited component size and post-processing are commonly acknowledged as such disadvantages. Therefore, this study includes specifically includes perceived disadvantages of metal AM.

Table 1: Operationalisation of the technological factors

Technological context	Operationalisation of the factors
Relative advantage	Perceived direct benefits (Kuan & Chau, 2001)

	Perceived indirect benefits (Kuan & Chau, 2001)
	Perceived disadvantages *(specifically included in this study)*
Compatibility	Metal AM fits with existing hardware in the organisation (Waarts et al., 2002)
	Metal AM fits with existing software in the organisation (Waarts et al., 2002)
	Existing production personnel is only familiar with proprietary production methods (Chau & Tam, 1997)
	Metal AM is completely compatible with organisation's current business model(Moore & Benbasat, 1991)
Complexity	Expecting that it is cumbersome to work with metal AM(Elbertsen & Reekum, 2008; Moore & Benbasat, 1991)
	Expecting that it requires a lot intellectual effort to work with metal AM(Elbertsen & Reekum, 2008; Frambach, 1993; Moore & Benbasat, 1991)
	Handling metal AM is expected to be simple (Elbertsen & Reekum, 2008; Frambach, 1993; Moore & Benbasat, 1991)
Trialability	It was possible to try out a metal AM system a certain period of time (Frambach, 1993)
	Organisation has had a great deal of opportunity to try out various AM applications (Moore & Benbasat, 1991)
	Organisation knows where to go to satisfactorily try out various uses of AM systems (Moore & Benbasat, 1991; Park & Chen, 2007)
Observability	Presence of a clear business case to justify the investment *(specifically included in this study)*
	It is easy to see others using metal AM in my work (Park & Chen, 2007)
	There is a lot of opportunities to see metal AM being used outside the organisation (Park & Chen, 2007)

Organisational context: operationalisation of the constructs

Organisational context refers to characteristics internal to the organisation, such as the skills and resources an organisation assumes it possesses. The operationalisation of the organisational context is presented in Table 2. Organisational slack is explained in more detail in this paragraph.

Organisational slack is defined as the influence of uncommitted resources available to the organisation. This can either be financial or human resources. Unlike the definition of slack, which means waste, organisational slack is a much more positive organisational characteristic. It is desirable and beneficial, but not essential nor sufficient for innovation to take place. The other variables are presented in Table 2.

Table 2: Operationalisation of the organisational factors

Organisational context	Operationalisation of the factors
Financial costs	The influence of high operating costs(Elbertsen & Reekum, 2008; Kuan & Chau, 2001)
	The influence of high consultancy costs (Elbertsen & Reekum, 2008)
	The influence of high training costs(Elbertsen & Reekum, 2008; Kuan & Chau, 2001; Talukder, 2012)
	The influence of high non-recurrent set-up costs (Elbertsen & Reekum, 2008; Kuan & Chau, 2001)
Technological readiness	Presence of expertise in relation to metal AM (Kuan & Chau, 2001)
	Presence of experiences in relation to metal AM (Kai-ming Au & Enderwick, 2000)

Firm size	Influence of the size of the firm (e.g. number of employees)(Attewell, 1992; Chau & Tam, 1997; Zhu et al., 2003)
Organisational slack	Influence of uncommitted financial resources available to the organisation (Nohria & Gulati, 1996; Tornatzky et al., 1990)
	Influence of uncommitted human resources (e.g. redundant time) available to the organisation (Nohria & Gulati, 1996; Tornatzky et al., 1990)
Formalisation	Flexibility and low emphasis on work rules (Damanpour, 1991)
	Organisational regulations in which procedures are fixed (e.g. quality norms, non-disclosure agreements, recording job tasks and responsibilities (Frambach, 1993)
Centralisation	Lower management has a high degree of freedom to take independent decisions (Frambach, 1993)
	Important decisions within the organisation are taken in consultation with employees (Frambach, 1993)
	High complexity of its managerial structure (Chau & Tam, 1997)
Managerial support	Top management support for use of metal AM in the firm's operations (Premkumar & Ramamurthy, 1995)
	Commitment of top management to provide adequate financial and other resources for the development and operation of metal AM (Premkumar & Ramamurthy, 1995)
	Top management strongly encourages the adoption of metal AM (Lewis, Agarwal, & Sambamurthy, 2003b)[B]
	Top management will recognize my efforts in adopting metal AM (Lewis et al., 2003b)
Champion	Existence of single person committed to introducing metal AM in the organisation (Premkumar & Ramamurthy, 1995)

Environmental context: operationalisation of the constructs

Environmental context relates to factors that are a result of the arena in which the organisation operates, such as market structure and governmental regulations. This paragraph explains pressure from business partners in more detail. Pressure from business partners might imply that some kind of intimidation from suppliers or clients is involved. For instance, one of the biggest and therefore most influential clients of an organisation strongly requests the organisation to adopt a technological innovation, because otherwise the client does not want to conduct business with the organisation any more. This can be the case, however, is not the only definition of pressure from business partners. It is also about a client's or supplier's interest in the technological innovation. This might trigger the organisation to adopt the innovation for strategical reasons. The other variables are presented in table 3.

Table 3: Operationalisation of the environmental factors

Environmental context	Operationalisation of the factors
Pressure from business partners	Pressure from clients to invest in metal AM (Elbertsen & Reekum, 2008; Kuan & Chau, 2001)
	Pressure from suppliers to invest in metal AM (Elbertsen & Reekum, 2008; Kuan & Chau, 2001)
	Propensity to invest in metal AM because of clients' interest in metal AM (Elbertsen & Reekum, 2008)
	Propensity to invest in metal AM because of suppliers' interest in metal AM (Elbertsen & Reekum, 2008)
Pressure from competitors	Organisation feels threatened by competitors(Lee & Shim, 2007; J.-C. Wang & Tsai, 2002)
	Metal AM used by most important competitors (Kuan & Chau, 2001)
Social network	Contact of management with management of fellow organisations (Frambach, 1993)
	The existence of a lively network of formal and informal relations within the sector (Frambach, 1993)
	Exchange of metal AM experiences with people from outside the organisation (Elbertsen & Reekum, 2008)
	Value of the obtained information in an informal way (Elbertsen & Reekum, 2008)
Supplier marketing activities	Spontaneous awareness of AM suppliers (Waarts et al., 2002)
	Well-informed awareness about the of existence of metal AM suppliers (Elbertsen & Reekum, 2008)
	Organisation is faced with supplier marketing activities (Elbertsen & Reekum, 2008)
	Risk reduction activities from suppliers (e.g. trial period, low introduction price, lease construction) (Frambach, 1993; Van Der Sijde, Van Reekum, Jeurissen, & Rosendaal, 2015)
Governmental regulations	Funding regulations for metal AM adoption *(specifically included in this study)*
	Perceived government pressure (Kuan & Chau, 2001; Mellor et al., 2014)
Support infrastructure	Influence of a proficient AM supply chain (e.g. metal AM system vendor, material supplier, service provider, research institutes, consultancy bureaus) (derived from Mellor et al., 2014)
	Degree to which organisation is positioned near metal AM suppliers (derived from Mellor et al., 2014)

3.4 Data collection procedure

The research population that meets the classification requirements is small, as there are only a few adopters of metal AM systems in the Dutch manufacturing industry. However, Berenschot Group B.V. has a large network including several metal AM adopters, which allowed this research to aim for five adopting and five non-adoptingcompanies. Because the influence of the six buying roles is included in the scope of this research, it was intended to conduct multiple interviews per company. Besides gaining insight into the buying roles, conducting multiple interviews per company will also contribute to the accuracy and reliability of the collected data of a single organisation. A total of five adopting and five non-adopting organisations were interviewed.

It was expected that it would be difficult to find sufficient non-adopter respondents, because of the classification requirement that respondents should have considered adopting metal AM. As outsiders, it is difficult to acquire insight into the strategic plans of organisation and therefore difficult to assess whether or not a non-adopter organisation considered to adopt metal AM. However,we anticipated in order to minimise the risk of not being able to find enough respondents, by utilising the network of metal AM systems suppliers. The network of Berenschot also includes such metal AM system suppliers, who were contacted to participate in the research. Participating meant that they provided us with companies who have considered to adopt metal AM but, in the end, chose not to adopt. In return, the outcomes of the research are shared with the participating suppliers. Also, metal AM systems suppliers benefit by reinforcing metal AM awareness among non-adopter companies and thus creating more awareness of metal AM technologies in general.

Respondents were preferably contacted by phone. An e-mail was sent in case the potential respondent could not be reached. As a follow-up, the Research Invitation in Appendix A was sent which included an introduction to the research, an explanation of the relevance of the research and the procedure in case the respondent wants to participate in the research. In case the respondent agreed upon participating, the Interview Structure Form was sent to the respondent. However, no preparation was required. The Interview Structure Form that was sent to the respondents can be found in Appendix B. Appendix C is an overview of the Interview Structure Form that was used by the interviewer, which is an extended version of the respondents’ one. Also, we ensured that the respondents filled out the Consent Form so that the interviews could be recorded in order to improve the reliability of the data analysis, see Appendix D. The Consent Form also ensured that data was treated anonymously and confidentially. The duration of the interviews was estimated at approximately one hour, depending on the buying role(s) of the respondent.

The TOE-framework from figure 1was used as the structure for the in-depth interviews. The operationalisation of the factors was utilised to provide additional information in case the question was unclear to the respondent. Questions were asked in random order, depending on the answers that were given, as a semi-structured interview befits. However, every interview began with an introduction of the respondent and determining the buying role(s). Hereafter, the interview was continued with the first question: “Which factors were most important for you/your organisation in the adoption decision process?”

3.5 Data analysis procedure

To analyse the interviews, the following structure was used:

1. Transcripts were made as this will help to better code and organise the data and thus will contribute to the reliability and validity of the research;
2. We coded and qualified according to the operationalisation of the factors from section X, using Nvivo software. This will improve the objectivity of the data analysis.
3. The results of the coding process are presented in tables in appendix X to give an objective and reliable view of the gathered data.
4. The data are interpreted in two steps. First, the main differences and similarities between adopters and non-adoptersare described. Second, the interrelations between the TOE framework and the six buying roles are covered.We, however, managed to conduct only 1.3 interviews per company on average. Because not all buying roles were addressed sufficiently, we decided to conduct three more interviews at one more company, currently considering the adoption decision.

In summary, the research methodology was discussed to give enough information to replicate the study. We chose to use a qualitative research approach in order to extend the TOE framework by studying the interrelation with six buying roles. Figure 1 was utilised as a research framework for the research methodology. As a preparation for both, the semi-structured interviews and data analysis, the 19 factors within the technological, organisational and environmental context were operationalised. Also, insight was provided in the data collection and data analysis procedure to allow replication of the study.Altogether, the explanation of the research methodology allows us to continue with presenting the results in the next chapter.

4. Results

This chapter aims to describe patterns that were observed during the analysis of the data. The results are presented as follows. First, the relevance of the TOE framework is addressed. Next, the TOE framework is covered by discussing all 19 factors within the technological, organisational and environmental contexts. Finally, the six buying roles as stressed by organisational buying behaviour literature are described.

Relevance of the TOE framework

First, the relevance of the framework is discussed. We, however, do not have sufficient data for proving statistical significance, hence we base this conclusion on the respondents' finally remarks at the end of the interview. The following question was asked at the end of each interview: 'Which factors did we not cover that influenced whether or not to adopt metal AM for you/your organisation?'No respondents thought the research framework was incomplete, only positive feedback was received:

> 'It is obvious that you took the right path to get a complete overview'. (Respondent X).
>
> 'I think these are all good pointsbecause I've thought about the most'. (Respondent Y).

Furthermore, in appendix E all results are qualified according to the operationalised factors from table 1, 2 and 3. The acquired data substantiate the relevance of the research framework. The results are discussed in the next sections accordingly.

4.1 The influence of the factors within the technological context on the adoption decision

Relative advantage

The direct benefits, indirect benefits and perceived disadvantages are discussed separately. First, both adopters and non-adopters agreed on the direct benefits of metal AM. We distinguish three categories of benefits from the respondents' data: complexity, speed and low volume production. Especially complexity is named as a major benefit of metal AM: 'The biggest advantage is making products quicker and more complex' (Respondent C). In addition, respondent B mentioned thatbeing able to produce more complex products relative to conventional manufacturing techniques allows the production of coarse structures, perfectly suitable for medical implants:

> ‘3D printing allows creating open coarse structures which are ideal for certain groups of medical implants. And, this cannot be produced with other technologies. That is the main advantage’. (Respondent B).

The ability to produce more complex products is also perceived as a possibility to design products with as few parts as possible: ‘Because there is more freedom of form, and I’ve always been an advocate of using as few parts as possible in steel constructions’ (Respondent X).Taking indirect benefits into account, it is noticed that both adopters and non-adopters emphasise the importance of organisational image. Several adopters stated that this is one of the most important reasons to adopt new technological innovations such as metal AM.

> ‘My most important reason was, I wanted something new for my company. How do I get attention as a company? And then it is more a commercial factor than a technical factor. How can I draw attention to ourselves other than being a small stupid machining company?’(Respondent D).

Finally, it was noticed that non-adopters accentuate the perceived disadvantages much more than adopters. These disadvantages mainly refer to technological limitations, such as a slow production speed:

> ‘We miss making heavier products, weight and production speed’. (Respondent Y).
>
> ‘But, the costs and slow production speed are perceived as insufficient to make it profitable’. (Respondent V).

Compatibility

Both adopters and non-adopters perceived a certain degree of fit with proprietary equipment such as lathes and milling systems.This was stressed as an important reason to consider adopting metal AM. One adopter stated that the fit of metal AM with their current machining and chemical processing systems wasan important factor:

> ‘Our competences characterise that we have all the means to bring a medical implant from start till a final product to the market, clean and engraved. Therefore, we are relatively unique, there are more like us, but we are relatively unique. And 3D printing is also one of the competences we want to add, because it is not a final product, but it is a processing technology. Thus, within our competences of machining, turning, milling, wire EDM, eroding, but also chemical processes, in fact, we are only adding one more competence to this. (Respondent B).

Non-adopters also found this factor to be important and generally did not perceive a lack of compatibility as a reason to not adopt. Respondent Z2 highlighted that they are well positioned to adopt metal AM because of ‘the combination with post processing certain parts of the product’.

Considering the compatibility of metal AM with the business model, we observed some differences between both adopters and non-adopters. Non-adopter respondent V argued that they did not invest because the business to consumer industry in which they operate is extremely conservative in such way that their client requests the same products, resulting in a very cautious approach when utilising new technologies. More non-adopters perceived a lack of alignment with their business model, however,stressed this as a must have:

> ‘But, we look very critically if it fits with the product that we make for our clients, and what our customers are up to. And what I already said, these are industrial clients and they want industrial products that do not have to be very lightweight. Those are major parts of about 50 kilograms up to a few hundred or thousand kilograms. […] To a certain degree, metal printing would be compatible with the company, but the technology does not align with our industrial clients.’ (Respondent Y).

In general, adopters agreed that business model alignment is important, but, in contrast to non-adopters,perceivedmetal AM as an extension to their current business model which perfectly aligns with the way they capture value. One of the most important reasons for respondent C to adopt was:

> ‘Because we are a contract manufacturer, where we utilise manufacturing technologies to add value to our customers. We see manufacturing possibilities with 3D printing which we cannot produce with our current technologies, or possibilities to better integrate things.’ (Respondent C).

In conclusion, both adopters and non-adopters agree that compatibility is an important factor when considering the adoption decision. The fit with hardware and software is more or less equal between both. In contrast to non-adopters, adopters generally perceive a certain degree of alignment with their business model.Nonetheless, this perception does not always turn out to be true: ‘Previously, we thought that it would be compatible with our business, but we are still not sure if that is the case. Is it compatible with our business?’ (Respondent A1).

Complexity

Three out of five adopters admitted that they were little unaware of the complexity of metal AM, explaining that they underestimated the technology on beforehand:

> ‘Everyone thinks that you just press a button and then a product will be released. And that is not the case. There is another step, defining the right parameters, and that is the complexity of the printer. In terms of programming it is maybe simpler than our current machines, but defining the settings, the parameters have to be spot on. And that is actually the complexity of the printer. This was underestimated, but everyone does that. I can tell you, every client that comes to us thinks that it is just about pressing a button. And obviously, we thought exactly the same in advance.’ (Respondent A3).

> ‘It is pretty complex, and I have to admit that this is something which I underestimated’ (Respondent E).

> ‘We obviously thought, alright, there are some challenges. But, we expected the technology to be a little bit more mature. Although, we also saw some examples that the technology was not so mature yet. But, we did not have that experience.’ (Respondent C).

Another adopter used a trialability phase to allocate the complexity and reduce uncertainties:

> ‘During that [consortium] period we found out that it is really hard to make something good and manageable, which meets that quality norms and is reproducible. Some of these risk were identified and acknowledged during this consortium period. It made us choose for our current machine. […] We have used that period to identify and if possible reduce the risks.’ (Respondent B).

Non-adopters generally stated the complexity to be bridgeable. Respondent Z2 mentioned that: ‘it is more complex than you would expect, but if you allocate and decrease the risks, we expect it to be a relatively standard process. And, this process has to be designed, which will be complex, but after this is done, it can be standardised.’ Another non-adopter said that metal AM is a complex technology, which must not be underestimated:

> ‘Metal printing should not be underestimated, if you want to start printing, you have to spend half a million, you also need to have space, and some infrastructure around it. In addition, you need to have at least two decent operators that will costs you money, and if you do not make any profit, then you need to a lot of money to keep that up. Not everyone can do that I think, and certainly not a small medium enterprise. And I think that everyone copes with that and that the ones who invested found out that it is not so easy after all.’ (Respondent Y).

Trialability

Trialability seems to be an important factor for both adopters and non-adopters to create an opinion about the potential value of metal AM for their organisation. In general, both knew and were able to try out metal various applications. Two adopters tried out metal AM during a period of three years in collaboration with multiple other companies so that the investment was more advantageous and the learning curve steeper than doing everything on their own. This type of trialability turned out to be instrumental for these two adopters:

> ‘Collaborating was one of the reasons. I think that it results in a steeper learning curve’ (Respondent C).

> ‘So we said, we are going to work with it. It did become easier because we could split our costs with multiple other companies. That saves an enormous amount of money. I’m not sure what we would have done without such a collaboration’. (Respondent C).

> ‘If we would have done it at our own risk, it would cost us triple the amount. Without this period, for sure we would not have invested in 3D metal printing, no, we could not make that decision.’ (Respondent B).

Furthermore, we observed that several respondents adopted plastic AM systems to raise 3D print awareness throughout the organisation:

> ‘Before that, we started with installing an Ultimaker at our engineering department. So, before we joined the consortium. To raise awareness.’ (Respondent C).
>
> ‘We started with an FDM printer. […] Printing plastics was initiated by me, I have to involve the rest of the company as well.’ (Respondent Y).

Overall, we state that the ability to try out various AM applications is likely to influence the adoption decision. For two adopters experimenting with metal AM in collaboration with other companies was essential. Besides this, more types of trialability were mentioned (e.g. service providers, research institute, plastic AM). Because non-adopters also knew and were able to try out various AM applications, we conclude that trialability does not necessarily positively influence the adoption decision. It, however, played an important role regarding the adoption decision of our respondents.

Observability

Two types of observability are discussed, the visibility of the innovation and the degree to which the outcomes of the innovation are communicable to others. Metal AM turns out to be very visible as multiple respondents explained they have seen others using the technology. The visibility of metal AM is especially present at fairs. It seems to trigger companies to consider adopting metal AM and supports in creating an opinion about metal AM.

> ‘In fact, I come across many things during company visits, at fairs and during networking. And at a certain moment, you’ll create an opinion about metal AM.’ (Respondent W).
>
> ‘The technological progress on increasing building speed goes terribly slow, I visit all those fairs and it does not improve. For the time being not at least.’ (Respondent Y).
>
> ‘It was initiated by someone from top management who saw it at a fair.’ (Respondent A3).
>
> ‘Since 2012, we see more and more 3D printed medical implants at conferences and fairs. First as sample and prototypes and then more and more with business partners who did it as volume production.’ (Respondent B).

Furthermore, the presence of a clear business case to justify the investment also influences the adoption decision. We found a distinct pattern for both adopters and non-adopters. On the one hand, four non-adopters attached great importance to developing a clear business case. It was mentioned by multiple non-adopters as one of the main reasons to not adopt. On the other hand, four adopters described that they did not think the business case was really important. Some of them mentioned that they based their adoption decision on a gut feeling. We point out three quotes that underline this observation:

> ‘Such an investments is really something that must be based on a cost-benefit analysis.’ (Respondent Z2).
>
> ‘You want to be flexible, and you don’t do that based on comprehensive studies and business cases, but for an important on a gut feeling. […] I think that it is not possible to quantify. In bigger organisations that might be different, adoption decision processes are probably done differently and involving more people. I’m not sure if such an approach is better than ours.’ (Respondent B).
>
> ‘We have a few hundred clients in very diverging industries, so we don’t know what kind of work we have to do tomorrow. There are no products which we have to produce on a weekly basis. Several jobs come in repeatedly. But, it is mostly guesswork. It includes many assumptions. That is a risk, a gut feeling.’ (Respondent E).

One adopter however emphasised the importance of a clear business case for their adoption decision. He also stated that it was very hard to develop a proper business case. Hence, this company chose to collaborate with other companies so that it was easier to justify the investment, because the costs were split amongst multiple companies.

4.2 The influence of the factors within the organisational context on the adoption decision

Financial costs

We did not find distinct perceptions about the financial costs of metal AM between both adopters and non-adopters. Two non-adopters pointed perceived high financial costs out as the main reason to not adopt metal AM.

> Until now it was a real explorative research, which we did not continue, because of the high financial costs. These costs are estimated at approximately €1.000.000,-. (Respondent V).
>
> ‘It is mainly because of the investment costs, which are relatively high. Two years ago I started orientating on the possibilities and associated costs. But, the current metal printers have a fairly compact building volume. You also have bigger systems, but the price increases exceptionally. And, it does not end with investing in a metal printer. You need much other equipment to deliver your print to the customer. […] And, this gives such a high investment that my clientele is not big enough yet.’ (Respondent X).

Two adoptersalso stated that the financial costs almost influenced the adoption decision negatively, but they were able to collaborate with multiple other companies to lower initial investment. Respondent C mentioned that it: ‘became easier to adopt, because the costs were divided amongst several organisations.’ This enabled them to adopt metal AM. The other three adopters also perceived the financial costs as relatively high, though this was not seen as a hurdle to withhold them from adopting.

Technological readiness

Both adopters and non-adopters perceived a certain degree of presence of expertise and experiences in relation to metal AM.There was, however, no specific metal AM knowledge present atmost respondents in the adoption process. Two adopters chose to hire 3D experienced personnel:

> 'We hired all new experienced 3D printing personnel. Only one current employer was involved, he became an operator. Furthermore, expertise was bought from the market, so people were hired who possessed much expertise.' (Respondent B).
>
> 'Were we ready? Technically not. We have hired someone new'. (Respondent E).

Non-adopters generally did not perceive a lack of AM related knowledge which discouraged them to adopt. Even one non-adopter respondent emphasised that he found his company well positioned to adopt metal AM, partly due to the amount of relevant knowledge the organisation possessed.

> 'I always thought that we were very well positioned to adopt metal AM, because of several reasons. We do a lot of engineering, so we have a complete 3D engineering department. Also, we calculate the weight and strength of products, which is really beneficial for 3D metal printing. Thus, we do all kinds of engineering inhouse, we have knowledge about that. Furthermore, we have knowledge about material, including metal. Not about powders, but about characteristics.So we know everything about carbon diagrams and material deformation, we have a lot of knowledge. Also, we have materialspecialist and we are able to post process, so therefore I always thought that we were very well positioned to adopt metal AM.'(Respondent Y).

Firm size

Firm size was one of the least discussed factors during the interviews. According to Iacovou et al.(1995) it seems logical that larger firms are more likely to adopt innovations, because they possess a higher level of resources and thus are more likely to i.e. profit from economies of scales (Tornatzky et al., 1990). But, no indisputable link between this factor and innovation has been established in thecurrent literature. The impact of firm size might be expressed by other factors within this framework such as organisational slack. Therefore, we do not conclude that firm size is seen as an irrelevant factor when considering to adopt metal AM. Additionally, we want to point out a statement from an adopter which shows such link between firm size and organisational slack:

> 'Our company is a big, big company and there is a lot of money. So financially, you are able to invest in such things. If you have a small company, the financial impact is much bigger.' (Respondent A3).

Organisational slack

The number of uncommitted financial and other resources seem to influence the adoption decision. Respondent A3 mentioned that slack was present due to the size of the firm, which enabled them to invest in metal AM. In total, three adopters described such alike influences of organisational slack.

One of the adopters mentioned that redundant time encouraged him to read specialised literature, which triggered the adopter to consider adopting metal AM.In addition, he stated that plenty liquidity available was crucial to make a positive adoption decision:

> 'For me, the most important reason to buy a metal 3D printer, […], was the fact that liquidity was available to invest in innovative equipment.' (Respondent C).
>
> 'Without such financial space, I would not have invested.' (Respondent C).

Organisational slack was also available for two non-adopters, but due to other reasons, they decided not to invest in metal AM. Another non-adopter mentioned that the absence of organisational slack discouraged them from adopting metal AM. Respondent Z2 explained that overcapacity was less present due to pressure from competition, which hindered the adoption.

Formalisation

Organisational regulations in which procedures are fixed (e.g. quality norms) influenced the propensity to adopt. In contrast to what was found in literature, two adopters explained that their quality norms encouraged them to adopt metal AM. Respondent A3 explained that the quality certification AS9100 they acquired, allowed them to manufacture for the aerospace industry. According to respondent A3, the ability to produce strong lightweight products with metal AM,is ideal for this industry. Hence, these quality norms stimulated them to adopt metal AM:

> 'In 2011, we received the AS9100 certification, and at a certain moment 3D metal printing was discussed, and we also discussed that it enables to generate specific geometries to optimise the ratio between strength and weight so that the same product could be produced much lighter. And this is ideal for the aerospace industry.' (Respondent A3).

Furthermore, four non-adopters made clear organisational regulations did not hinder the adoption decision. Two quotes are shown that underline this observation:

> 'The certification process is in its infancy. We are currently busy with the certification so that we can communicate with our business partners that we are able to produce certified parts. […] I'm aware of it, but it is not a barrier.' (Respondent X).
>
> 'We have obtained our ISO-certification so that we can prove that our products are produced by means of a strictly regulated process, including traceability of materials and so on. The systems have to be compatible with this, material management, traceability, all must be tested so that if you change materials, you do not have contamination and so on. But, I think that this not really played an important role. We are not yet in the phase that this plays a decisive role.' (Respondent Z2).

Centralisation

Both adopters and non-adopters perceiveda lot of power in the hands of relatively few. This automatically means that the opinion of these few individuals is crucial in the adoption decisionprocess. This opinion both negatively and positively influenced the adoption decision. For three adopters, it positively influenced the adoption decision. Respondent D mentioned this as a substantial advantage, because it allowed him to take an impulsive decision.

> ‘I have the advantage that I do not have to ask for permission. Nobody will ask me, [Respondent D], did you substantiate that decision properly, did you make a proper analysis? A SWOT analysis?I know in my mind that I can do it, so I will do it. This also means that you can do things too impulsive though.’ (Respondent D).

On the other hand, three non-adopters stated that they have to justify such investments to the parent company or CEO or consult it with other members of top management:

> ‘The only thing that we need is an approval of the major shareholder’. (Respondent W).

> ‘I do not take that decision solely, we have a management consultation about it. What do we think is important and where do we believe in? But, someone has to ultimately take the decision and that is me.’ (Respondent Y).

> ‘Basically, I’m just one of the ten partners and because it is my business I will possess much power, but there is one main financier which ultimately approves the adoption decision.’ (Respondent Z2).

Managerial support

Just like firm size, managerial support seems to be one of the least discussed factors during the interviews. We mainly interviewed people from top management, which might be the reason that the impact of this factor was not discussed in much detail. Therefore, we do not want to conclude that the factor does not influence the adoption decision. Hence, no patterns nor differences are found in the data.

Champion

A champion was present at both adopting and non-adopting companies. In general, both categories emphasised it as important factor and stated that without a champion a decision would not have been made. For three adopters, we clearly observed that this one person was also highly enthusiastic and committed to introducing the technology in the organisation. These adoptersalso emphasised the significance of this factor:

> ‘In the adoption decision process it was my main responsibility and I was also the one that would become responsible for this department. […] I think that a champion is essential in such small environments.’ (Respondent B).

> ‘If I did not take this responsibility, we would not have been where we are now.’ (Respondent C).

> ‘In this case, new technologies and so onare my responsibility as a director and owner. So that is completely my responsibility. I put a lot of effort in it and I have to pay it as well. […] Thus, I’m the champion and I think thatis really important.’ (Respondent E).

Two non-adopters also underline the importance of a champion. Nonetheless, they did not yet invest in metal AM due to other reasons. Thus, the presence of a champion seems to play an important role for both adopters and non-adopters, but it is not sufficient for adoption to take place.

4.3 The influence of the factors within the environmental context on the adoption decision

Pressure from business partners

Market developments tend to be very important in considering whether or not to adopt metal AM for both adopters and non-adopters. It is the interest of clients which influences the propensity to adopt for adopters. Respondent B found market developments one of the most crucial factorswhich led to adopting metal AM:

> ‘Market developments. In other words, our business partners became more and more active in the field of 3D printed medical implants.’ (Respondent B).

Only one adopter respondent did not take this factor into account at all.Most non-adopters also found this factor to be important. However, the non-adopters perceived too little pressure nor interest from their business partners, resulting in a negative adoption decision. Respondent W was on the edge of adopting metal AM in collaboration with several other companies. Unfortunately, these companies decided not to adopt, because there was too little pressure from business partners.

> Besides this, all companies tried to estimate how much work they could pull out of the market, to fill 40-50% of the metal printer. And, this has been insufficient. The demand from the market is inadequate.’ (Respondent W).

Pressure from competition

In general, both adopters and non-adopters perceived a certain degree of pressure from competition. However, the way they dealt with this pressure tends to be slightly different. In most of our cases, adopters translatedthe pressure from competitors into something which positively increased the propensity to adopt. For adopters, it resulted in the drive to create or sustain a competitive advantage by distinguishing themselves from competitors in a unique way.

> ‘What the owner of [company A] always says, is that we want to sustain a competitive advantage with respect to our competitors. We want to have such a system before they do.’ (Respondent A3).

> ‘We are seen as an innovative and leading company. And if you do not want to lose such an image, you have to stay ahead. That was a reason for us, because we want to stay ahead of our competitors.’ (Respondent E).

The drive to adopt metal AM due to the pressure from competition seems to be less valid for non-adopters. Two non-adopters did not mention pressure from competition as a factor which influenced the adoption decision. One non-adopter emphasised that pressure from competition is present, but that it made the company compete with their competitors through low-priced products, hindering the adoption of metal AM.

> ‘Overcapacity is less present, because of the pressure from competitors which hinders the adoption.’ (Respondent Z2).

Social network

Contact with themanagement of fellow organisations or the existence of lively networks within the sector tends to influence the adoption decision. Most adopters highlighted the influence of this factor as substantial. In some cases, it functioned as a trigger to consider adopting metal AM.

> ‘We collaborate with all companies that do thermal spraying. We have an association of which I’m part of the board. 3D printing received my attention because I see a future in combination with laser-cladding. […] Social network is really important, because it opens up new markets. Also, it triggered the interest in laser-cladding.’ (Respondent E).

> ‘Social network is really important for us. We joined a network of companies’. (Respondent C).

In contrast, for non-adopters it seemed to play a less important role. Two non-adopters did not mention the influence of a social network. In addition, one non-adopter stated that the presence of contact with management of fellow organisations resulted in a negative perception about successful implementation of metal AM.Ultimately withholding them to adopt:

> ‘And that is what I also see around me with 3D metal printers, people have completely no clue about what they are doing. Most of them also do not have any understanding at all about materials, which is extremely important.’ (Respondent Y).

Supplier marketing activities

All respondents noted that they were faced with supplier marketing activities. Most adopters and non-adopters actively visited fairs to acquire information about the technological innovation. No distinct patterns between both adopters and non-adopters were found. Nonetheless, we observed risk reduction activities from suppliers towards three adopters. One supplieroffered an adopter a financial lease arrangement, which was emphasised as crucial for the adopter. Another supplier reduced the adopters’ risk by offering the ability to try out the metal AM system for a certain period of time. This supplier also offered to deliver a certain amount of 3D print work, so that the adopter would not have to worry about this anymore and thus reducing the risk of adopting a metal AM system. Finally, a third supplier designed the metal AM system specifically to the needs of adopter. Non-adopters did not mention similar risk reduction activities. Though, two non-adopters accentuated the importance of risk reduction activities, by stressing that they would want to benefit from alike deals. These quotes underline the three risk reduction activities that we addressed:

> ‘In the deal we made we agreed to get a certain amount of 3D printing work. And, because this was ensured, we did not really think about getting enough work on our own because we would get enough work anyways.’ (Respondent A3).
>
> ‘Currently, we have a dual laser metal AM system but our trialability phase was the fact that we could experiment with a single laser metal AM system at first. We could try it out to find out if everything went well. This was a deal. You make a deal before you will make such an investment, including a cancellation clause.’ (Respondent A3).
>
> ‘I leased the printer, a financial lease, so I do have these commitments. I would probably have not invested if I needed to pay €250.000,- at once. Because then it would have cost me too much money at once. We would have endangered the liquidity of the company. […] Altogether, the financial arrangements were really important for me and Trumpf did have financial services, which was essential for me. Especially the spread payment.’ (Respondent D).
>
> ‘In the beginning, I selected the supplier who was best able to assist me in making a tailored systems. The system is made based on our requirements. Because of this, we chose this system supplier.’ (Respondent E).

Governmental regulations

According to both adopters and non-adopters, no governmental pressure to adopt metal AM is perceived.Furthermore, governmental regulations such as funding regulations seem to have little impact on the decision whether or not to adopt metal AM. Most respondents stated that funding regulations do not function as a trigger to think about adopting a technological innovation in the first place. Nonetheless, they try to profit from such funding regulations after the adoption decision is made. The following quotes underline this observation:

> ‘We did not consider governmental regulations. Afterwards, we found out that you could get funding because you produce less waste. But in the end, this was also a bit of a burden on the leg. You have to meet up with a lot of administrative requirements and so on, and we did not do that. But, before we adopted, we did not consider this.’ (Respondent A3).
>
> ‘In the beginning, this did not play a role. At the moment that we want to invest, we will try to find out which funding regulations we could utilise. But, we do not use these funding regulations as a basis to select a metal AM system so that we could get the as much funding as possible.’ (Respondent X).

Support infrastructure

In general, both adopters and non-adopters perceived the presence of a proficient AM supply chain. Mainly service providers, systems vendors and research institutes are utilised to acquire information about the technology. No distinct patterns between adopters and non-adopters were noticed. One non-adopter, however,emphasised that the presence of service providers is one of the major reasons to postpone the adoption decision. Respondent Z2 mentioned the following:

> ‘Support infrastructure plays a role in the fact that there are multiple parties where we could outsource. This is fairly accessible and causes that we delay adopting on our own. It makes it less relevant to have the technology in house, we are not dependent on it. So, we can outsource it to multiple service providers that are able to print things for us. And because it is a new technology, every week the systems become better and cheaper, we keep delaying it. As long as our current production equipment is not fully occupied, we keep delaying it.’ (Respondent Z2).

4.4 The interrelation between six buying roles and the TOE framework

The table in Appendix E is an overview of the corresponding buying role(s) of each respondent. The next paragraphs analyse the distinct characteristics and patterns from these six buying roles accordingly.

Decider

In total five respondents were recognised as deciders. All deciders performed multiple buying roles and were closely involved in the buying process. Four deciders were also identified as initiator and all deciders performed the purchaser role as well. Four out of five had a technical background. Only one decider had a financial background.We observed that a variety of factors from all three contexts, technology-organisation-environment, were mentioned as very important by the five deciders. First, taking the technological context into account, three deciders emphasised the importance of the relative advantage of the technology to consider the adoption decision.Respondent E said:

> ‘We chose to adopt laser-cladding,because it applies minimal amount of heat into the part.’ (Respondent E).

Also, three deciders considered indirect benefits such as an improved organisational image as an important reason to adopt.One of them stated that:

> ‘My most important reason was, I wanted something new for my company. How do I get attention as a company? And then it is more a commercial factor than a technical factor. How can I draw attention to ourselves other than being a small stupid machining company?’(Respondent D).

Financial costs, champion and centralisation were most crucial factors for deciders from the organisational context. All deciders highlighted the presence of the champion as very important.

> ‘I think that a champion is essential in such small environments.’ (Respondent B).
>
> ‘Thus, I’m the champion and I think that was really important.’ (Respondent E).

> 'If I don't take the responsibility, no one else will take over the responsibility.' (Respondent W).
>
> 'If I wouldn't be here, I should have been replaced by someone else with the role of champion, this is essential.' (Respondent Z2).

The influence of financial costs was stressed by all deciders as well but especially two non-adopters pointed this reason out as one of the major barriers not to adopt.

> 'It is mainly because of the investment costs, which are relatively high.' (Respondent X).

In addition, all deciders recognised themselves as a champion and highlighted it as essential in order to make a decision. Moreover, all deciders possessed much power to take decisions. One of them mentioned that this important decision was not taken in consultation with employees and therefore positively influenced the adoption decision. Respondent D mentioned the following:

> 'I have the advantage that I do not have to ask for permission. Nobody will ask me, [Respondent D], did you substantiate that decision properly, did you make a proper analysis? A SWOT analysis?I know in my mind that I can do it, so I will do it. This also means that you can do things too impulsive though.' (Respondent D).

From environmental context point of perspective pressure from business partners and pressure from competition are referred to as influential factors by the deciders. Respondent B said that market developments, described as the client's interest in metal AM, was their major reason to adopt.

> 'To serve our business partners. We think it will become such a major business that our business partners will ask us to play a role in this.' (Respondent B).

Altogether, we conclude that the decider is influenced by technological, organisational and environmental factors, which is in line with our proposition. The results, however, do not imply that the decider is mainly influenced by environmental factors as we argued in section 2.2.

Gatekeeper

This analysis is based on the gathered data from three respondents. Two out of three gatekeepers that were interviewed, functioned as an intern trying to find out the potential added value of metal AM for the organisation. Hence, both were classified as gatekeepers, as they controlled information to their supervisors. Respondent Q2 was also classified as a gatekeeper, because Q2 controlled access to information to others in the company. All respondents were mainly influenced by the perceived characteristics of the technological innovation in order to create an opinion about the added value of metal AM. Q2 was the only employed gatekeeper we interviewed. He described his job as atechnology manager. According to respondent Q2 it comprised the following:

> ‘My job entails that I’m working with new technological innovations. I keep an eye on new technological developments and interrelate them with our business. I also have to ensure that it is not necessarily a theoretical exercise, but I have to practically apply this knowledge. My speciality is laser welding, so I keep an eye on everything that has something to do with lasers. In addition, I try to bring together questions from our clients with technological developments. So, I work on the edge of technological developments from suppliers, I visit conferences, visit our clients and I am also occasionally in touch with universities. Our end customers are mostly car manufacturers. I try to do research about how we can add value for our end customers. Altogether, it is a strategic process to make things happen in our company, especially in the field of laser technology or welding technology.’ (Respondent Q2).

Altogether, respondent Q2 was mainly influenced by environmental factors such as pressure from business partners and support infrastructure. He combined this information with his interest in technological innovations. Although we managed to interview only a fewgatekeepers, it aligns with our proposition from section2.2, that the gatekeeper is influenced by environmental factors. But, our proposition must be refined, as it was noticed that perceived characteristics from the technological innovation also influenced the gatekeeper’s perception.

Influencer

This analysis is based on the data of seven influencers. Most influencers were part of top management and had a lot of power in the adoption decision process. Three out of seven influencers functioned as a director of the subsidiary, however, could not be classified as deciders because all of them had to consult such buying decisions with the director of the parent company or holding. For two non-adopters, this was crucial in the adoption process, as this led to a negative adoption decision. Respondent Z2 stated that currently, they have to justifysuch investments to the parent company, while this was not necessary before they were part of the parent company:

> ‘Such an investments is really something that must be based on a cost-benefit analysis. That was completely different in the past, when we bought our first milling machine, because we thought we wanted to play with it. The was a seven headed milling machineand costed at least one million, while we did not have any product to manufacture and sell yet. We thought that we needed it in the future, earned enough money with our other equipment and made this ruthless decision. […] That is currently financially much more difficult due to the increased pressure of competition and lower market prices. Hence, we have to substantiate our investments, not only to the parent company in America, but also because of our current financial numbers. […] Overcapacity is less present, because of the pressure from competitors which hinders the adoption.’(Respondent Z2).

Furthermore, in our proposition, we argued that the influencer is likely to be influenced by technological factors as well. Five out of seven influencers were part of or closely related to the research and development department. All of them stressed the influence of factors from the technological context. For instance, the relative advantage of metal AM in comparison to other manufacturing technologies was highlighted by all influencers. Three of them mentioned that relative advantage was one of the most influential factors:

> 'Technical possibilities were very important. You can produce parts which you, for example, cannot realise with a milling machine. This advantage is really important.' (Respondent W).
>
> 'New opportunities in product development are very important for us.' (Respondent Z2).
>
> 'It is mostly driven by the ability to develop flexible solutions and apply it to our current machines. That is a lot of potentialsin our industry. And I believe that this is a nice technology for this industry.' (Respondent Q1).

Initiator

Six respondents were identified as initiators. It was mostly performed as a secondary buying role and thus this paragraph aims to describe by which factors the initiator is triggered to consider adopting metal AM. We found that usually the initiator was triggered by a combination of technological and environmental factors, such as relative advantage, compatibility, observability, supplier marketing activities, pressure from business partners or social network. This aligns the proposition from section 2.2. The data from respondent B which substantiates this analysis is shown accordingly:

> 'Market developments. In other words, our business partners became more and more active in the field of 3D printed medical implants.' (Respondent B).
>
> 'You can see 3D printing emerge, that is why I put it on the agenda. That is how it starts.' (Respondent B).
>
> '3D printing allows creating open coarse structures which are ideal for certain groups of medical implants. And, this cannot be produced with other technologies. That is the main advantage'. (Respondent B).

Purchaser

Seven respondents were recognised as purchaser. This buying role was usually performed by someone from top management as a secondary buying role. Four out of seven deciders held the formal authority to select the supplier and arrange the terms of condition and were thus identified as purchaser as well. This aligns with our proposition, as we argued that the purchaser was likely to be a secondary role from someone from top management (e.g. decider, influencer).We, however, do not draw any conclusion, because we did not gather any purchaser specific data.

User

Three respondents were classified as auser. These respondents, however, had very distinct job descriptions, therefore we describe these respondents separately. A2 was a design engineer, already working amongst 25 years at the same company. According to respondent A2, company A decided to adopt metal AM without any consultation with the potential users. Respondent A2, however,was enthusiastic when top management asked who wanted to become the operator:

> 'I did not have anything to do with the adoption decision. That was only top management. After they bought it, it was reported to us. And then they asked us who wanted to work with the machine. I wanted to do that. I thought it was exciting, because it was new. I was very excited!'(Respondent A2)

The other two users played a bigger part in the adoption decision. Both, respondent V and X, had a technical background. Respondent X performed multiple buying roles but was triggered to adopt metal AM because of his previous engineering jobs. Respondent X was mainly influenced because of the production possibilities of metal AM in comparison with conventional production technologies.

> My engineering background triggered me to think about adopting a 3D metal printer because there is more freedom of form, and I have always been an advocate of using as few parts as possible in steel constructions. It reduces the amount of possible mistakes in the assembling process, because you use less and more similar parts. It simplifies the production process. Also, 3D printing of metal allows producing geometries which you cannot make with the current production technologies like turning and milling. Thus, in many cases, you can avoid additional assembly steps or reduce the amount of parts.' (Respondent X).

Furthermore, respondent V's job was team manager mechanical engineering. He was asked by top management to do research about the potential added value of metal AM, together with two others in the company. He was involved because of his technological know-how and ability to determine application possibilities of metal AM for the organisation.

Altogether, the results of both the 19 factors within TOE framework and the interrelation between the buying roles and the TOE framework were thoroughly analysed in this chapter. Overall, it can be concluded that the TOE framework was a suitable research framework for this research. Also, it was possible to observe interrelations between the six buying roles and the 19 factors within this framework. The technological, organisational and environmental contexts all included factors with a lot of impact on the adoption decision according to the respondents. Furthermore, we observed that the decider and influencer often also were recognised as initiator and champion. Hence, playing a crucial role in the adoption decision process. Within the next chapterthe results are discussed and a conclusion is given.

5. Discussion and Conclusion

This chapter aims to discuss our findings from the previous section. First, we reflect on some of the statements from the introduction and literature review while discussing the results. Second, we reflect on our research methodology and explain some of the limitations of our research. Also, suggestions for future research are addressed in this paragraph. Next, the practical relevance of the research is covered by discussing implications for both potential customers and metal AM system suppliers. Finally, the most important findings are summarised in the conclusion.

5.1 Discussion

Our findings suggest that technological, organisational and environmental factors influence whether or not to adopt metal AM systems. The impact of these factors is, however, different for both adopters and non-adopters. This paragraph aims to discuss most noticeable differences while reflecting on some of the statements from the introduction and literature review.Also,the interrelation between the buying roles and the technological, organisational and environmental context is discussed.

Technological context: discussing the findings by means of reflecting on literature

Tornatzky and Klein (1982) demonstrated that out of the five technological characteristics according to Rogers' DOI theory, relative advantage, compatibility and complexity have the greatest impact on the adoption decision at firm level. Our findings, however, indicate that for metal AM the trialability and observability tend to be important as well.First, the ability to try out metal AM on a limited basis (e.g. service providers) obstructed some non-adopters from adopting metal AM. A few non-adopters did not find it necessary to invest in a metal AM system, as long as they could utilise the services from service providers. For adopters, however, other forms of trialability positively influenced the adoption decision. Two adopters experimented with metal AM in collaboration with multiple other companies and stated that this was crucial for them in adopting metal AM.Second, the lack of communicable outcomes of the technological innovation by means of developing a business case obstructed the adoption of metal AM in several cases. While adopters generally did not require a clear business case, most non-adopters found this to be crucial. Nonetheless, both adopters and non-adopters agreedthat it is very hard to develop a business case for adopting metal AM. We found this to be one of the most noticeable differences between adopters and non-adopters. Furthermore, multiple authors (e.g. Kuan & Chau, 2001; Tornatzky & Klein, 1982)found that complexity negatively influences the adoption decision. Our results align with this, because non-adopters tend to perceive metal AM as more complex than adopters do.Also noticeable was the fact that most of the adopters stated that they have underestimated the complexity thus leading to a positive adopting decision.

Organisational context: discussing the findings by means of reflecting on literature

Within the organisational context, financial costs is one of the major organisational factors influencing the adoption decision (van Everdingen et al., 2000). Our findings suggest that financial costs indeed form one of the most important reasons for non-adopters not to adopt. The high investments in combination with the lack of building a business case was a crucial consideration for most non-adopters. Although adopters had similar perceptions about the level of investment costs, this did not obstruct them from adopting metal AM. We think that this might be explained because of two reasons. First, most adopters did not base their adoption decision on the presence of a clear business case. They emphasised the importance of acquiring knowledge about metal AM and improving or sustaining their innovative organisational image by adopting such technological innovations.Thus, the financial costs were stressed as not highly important by most adopters. Second, some adopters collaborated with several other companies to split the initial investments. They stated that the investment would have been too high if they did not have the possibility to participate in such consortium.Furthermore, in literature, we found that a high degree of formalisation usually has a negative impact on the adoption decision (Damanpour, 1991; Frambach, 1993). Although our findings do not suggest that the impact of this factor is substantial in comparison to other factors, it suggeststhat the emphasis on strict working procedures (e.g. meet quality requirements) might also positively influence the adoption decision. One of the reasons for this might be that metal AM is commonly applied in specific manufacturing sectors (e.g. aerospace, medical, dental). Thus, being certified to manufacture for such a specific sector with an enormous amount of quality norms might positively influence the adoption decision as adopting metal AM technologies creates new business opportunities.Moreover, while decentralised organisational structures are associated with adoption(Baker, 2012) our findings suggest the opposite is true as well. A high degree of power and control in the hands of relatively few didalso encourage adoption to take place, precisely because the decision is depending on relatively few. This means that relatively few individuals have to agree on the buying decision.

Environmental context: discussing the findings by means of reflecting on literature

The relevance of the environmental context in addition to the technological and organisational context has been acknowledged by numerous researchers (e.g. Chong et al., 2009), because it allows to better explain the adoption of technological innovations at firm level (Hsu et al., 2006). Hence, we included six environmental factors in our research framework. According to our findings, the influence of environmental factors was perceived as substantial. Pressure from business partners was considered to be crucial for both adopters and non-adopters. While adopters generally perceived a pressure from business partners, leading to a positive adoption decision, non-adopters perceived a lack of pressure from business partners. Also, it was observed that suppliers of metal AM systems seem to play a substantial role in the adoption process according to our findings. Both adopters and non-adopters mentioned risk reduction activities as crucial. We think that potential customers perceive much uncertainty when it comes to adopting metal AM, because it is a relatively new and immature technology. Technological developments seem to go at afast pace, which makes that companies find it hard to estimate at what moment adopting metal AM would be best for their company. Overall, we conclude that the environmental context in addition to the technological and organisational context must be considered when studying the adoption of technological innovations on firm level.

Buying roles: discussing the findings by means of reflecting on literature

In the literature, we also found that different educational backgrounds and experiences often generate substantially different goals (Sheth, 1973), making the adoption decision at firm level highly complex (Rogers, 2003). Hence, six buying roles were analysed in order to extend the TOE framework and gain more insight into the adoption process. Our findings suggest that members of the DMU usually have a technological background. We also found that the decider and influencerhave the biggest impact on the adoption decision of metal AM technologies. Often, the decider was identified as initiator and champion as well, leading to centralised decision structures with much power in the hands of relatively few, positively influencing the adoption decision. The influencer however was also often recognised as an initiator and champion, but did not possess the power to take such high investment buying decisions on its own. The adoption decision needed to be justified towards the parent company, CEO or major shareholder mostly by means of developing a business case. Altogether, integrating the six buying roles in the TOE framework allowed us to gain more insight in the adoption decision process.

Limitations and future research

Rogers(2003)developed a model toclassify five adopter categories (innovator, early adopter, early majority, late majority and laggard). Our research sample consisted of both adopting and non-adopting companies of metal AM systems. The respondents were recognised as early adopters because metal AM technologies are relatively new for theindustry.Tolbert and Zucker (1983) found that adoption decisions early at the innovation diffusion curve were influenced by other factors than later adoption. Hence, the insights derived from our early adopter respondents may not be representative for all potential customers of metal AM systems. In a further phase of Rogers' innovation diffusion curve, a quantitative research approach, including a bigger variety of respondents, could be utilised to acquire more generalizable results.

Furthermore, our research framework included 19 factors and six diverge buying roles to provide insight into the adoption of metal AM systems. The data were coded and analysed according to these factors. Our research might be biased by this TOE framework, as we unintentionally might have left out other affecting factors on the adoption decision of metal AM systems in specific. Nonetheless, 19 factors seem to be a major amount of factors to acquire useful and reliable data. For future research, it is recommended to use fewer factors based on our findings for two reasons. First, it enables us to isolate the most important variables. Second, it makes it easier to understand the adoption process (Chatterjee & Hadi, 2015).

In addition, we chose to gather data from adopters and non-adopters to observe different patterns within the technological, organisational and environmental context between both units of analysis. We also tried to describe the interrelation of the six buying roleswith the TOE framework. The major scope of our research result in a lack of focus at studying the interrelation of the buying roles.Hence, it was very hard to acquire useful data about these six buying roles and do proper analyses. We, however, still think that the addition of the role of individuals in relation to the TOE framework is useful, but should be studied in a more specific research. Therefore, it is suggested to observe the role of individuals within the DMU over a period of time at a single company who considers adopting a technological innovation. We think that this allows for a better theory building for two reasons. First, unlike our study, the adoption process does not have to be reconstructed. Instead, by analysing the adoption process over a certain period of time more reliable data could be collected. Second, the influence of the role ofindividuals is analysed within the same context, with the same organisational and environmental dynamics which allows focusing on researching the distinctions between the role individuals only.

Practical relevance for both potential customers and suppliers of metal AM systems

Furthermore, with this study it was aimed to provide thorough understanding into the adoption of metal AM. Our findings have practical relevance for both potential customers and suppliers. First, potential customers of metal AM could utilise these results and learn from adopters and non-adopters. As was clearly noticed that multiple adopters underestimated the complexity of metal AM and did not require a clear business case on beforehand, it is suggested to assess the economics and to utilise your social network in order to get a realistic view of the complexity technology so that disappointments are avoided when adopting metal AM. In addition, our findings from the non-adopters illustratea lack of pressure from business partners. Hence, we suggest to learn from adopters and aim to collaborate with business partners throughout the whole supply chain so that metal AM awareness increases, new business opportunities emerge and investment costs are lowered. Second, suppliers of metal AM systems could utilise these results as well. We suggest to assess companies based on AM activity throughout the supply chain and their innovative image within the supply chain, because adopters seem to be mainly driven by pressure from business partners and sustaining an innovative organisational image. In addition, non-adopters point out that a lot of uncertainty is perceived and that developing a proper business case is one of the most important factors that might lead to theadoption of metal AM. Therefore, suppliers might foster adoption by offering risk reduction activities to deal with such uncertainties. For instance, assist in defining a business case or provide insight into the expected technological developments of metal AM, so that potential customers are better able to assess when they want to adopt.

5.2 Conclusion

Our paper is one of the first theory-driven studies that aims to provide insight into metal AM adoption by means of integrating the role of individuals in the TOE framework. Insight was provided by discussing 19 factors within the technological, organisational and environmental context. In addition, the role of individuals as stressed by organisational buying behaviour was integrated into this TOE framework. The results of each factor, each buying role and the most noticeable differences were already discussed. Hence, this section aims to summarise most important findings of this research. First, the most important reasons for adopting companies to adopt are addressed. Second, the most important reasons for non-adopting companies not to adopt are covered.

For adopters, we found that relative advantage and trialability are important technological factors to adopt metal AM. In specific, sustaining or improving the organisation's innovative image, defined as an indirect benefit of metal AM, was stressed an important consideration resulting in adopting metal AM. Also, trialability positively influenced the adoption decision. Experimenting with metal AM in collaboration with multiple other companies was crucial for some adopters. Second, within the organisational context, centralisation positively influenced the adoption decision process, because it simplified the adoption decision process by involving as few individuals as possible. In addition, our data implies a double role between the decider and champion. Almost all adopters stressed a champion as crucial in the adoption decision process. Therefore, we conclude that it seems logical that this positively influences the adoption decision, as the individual whom has to ultimately approve the adoption decision is also the single person committed to introducing metal AM in the organisation. Such centralised structures, however, can also negatively influence the adoption decision. Third, within the environmental context pressure from business partners and supplier marketing activities were most noticeable factors positively influencing the adoption decision. Adopters generally perceived much pressure from business partners leading to a positive adoption decision. This pressure was mainly described as the interest of clients which increased the propensity to adopt. Also, it was observed that suppliers of metal AM systems seem to play a substantial role in the adoption process. These activities were described as risk reduction activities such as a financial lease arrangement.

For non-adopters, trialability and observability were important technological factors not to adopt. The ability to try out metal AM on a limited basis (e.g. service providers) obstructed some non-adopters from adopting metal AM. They did not find it necessary to invest in a metal AM system, as long as they could utilise from metal AM service providers. Furthermore, the lack of communicable outcomes of metal AM by means of developing a business case obstructed the adoption in several cases. Although both adopters and non-adopters agreed that it is very hard to develop a business case for adopting metal AM, most non-adopters found this to be crucial in the adoption decision process. Second, within the organisational context, financial costs and centralisation were pointed out as major hurdles. In terms of financial costs, the high investment costs in combination with the lack of building a business case was a crucial consideration for most non-adopters. Also,centralisation affected the adoption decision negatively for non-adopters. Often building a business case was a requirement from a superior whom possessed the power to ultimately approve the adoption decision. But as mentioned, it is currently very hard to develop a good business case to justify the investment in a metal AM system. Hence, the buying role, in most cases an influencer, was hindered from adopting metal AM due to such organisational decision structures. Third, within the environmental context, a lack of pressure from business partners and much pressure from competition negatively influenced the adoption decision. Some non-adopters stated that pressure from competition made their organisation compete with their competitors through low-priced products, hindering the adoption of metal AM.

6. References

ASTM International. (2013). F2792-12a - Standard Terminology for Additive Manufacturing Technologies. https://doi.org/10.1520/F2792-12A.2

Attewell, P. (1992). Technology Diffusion and Organizational Learning: The Case of Business Computing. *Organization Science*, *3*(1), 1–19. https://doi.org/10.1287/orsc.3.1.1

Baker, J. (2012). The technology–organization–environment framework. *In Information Systems Theory*, *28*, 231–245. https://doi.org/10.1007/978-1-4419-6108-2

Berman, B. (2012). 3-D printing: The new industrial revolution. *Business Horizons*, *55*(2), 155–162. https://doi.org/10.1016/j.bushor.2011.11.003

Brancheau, J. C., & Wetherbe, J. C. (1990). The Adoption of Spreadsheet Software: Testing Innovation Diffusion Theory in the Context of End-User Computing. *Information Systems Research*, *1*(2), 115–143.

Chatterjee, S., & Hadi, A. S. (2015). *Regression analysis by example* (Fifth edit). John Wiley & Sons.

Chau, P. Y. K., & Tam, K. Y. (1997). Factors Affecting the Adoption of Open Systems: An Exploratory Study. *MIS Quarterly*, *21*(1), 1–24.

Chong, A. Y.-L., Ooi, K.-B., Lin, B., & Raman, M. (2009). Factors Affecting the Adoption Level of C-Commerce: an Empirical Study. *The Journal of Computer Information Systems*, *50*(2), 13–22. https://doi.org/10.1080/08874417.2009.11645380

Damanpour, F. (1991). Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators. *Academy of Management Journal*, *34*(3), 555–590. https://doi.org/10.2307/256406

Dimple, Turska. Sujata, S. (2015). Organisational Buying Behaviour. *International Journal of Applied Research*, *i*(11), 391–393. Retrieved from www.allresearchjournal.com

Elbertsen, L., & Reekum, R. Van. (2008). To ERP or not to ERP? Factors influencing the adoption decision. *International Journal of Management and Enterprise Development*, *5*(3), 310–330. https://doi.org/10.1504/IJMED.2008.017434

Frambach, R. T. (1993). *De adoptie en diffusie van innovaties in de industriele markt.*

Frambach, R. T., & Schillewaert, N. (2002). Organizational innovation adoption: A multi-level framework of determinants and opportunities for future research. *Journal of Business Research*, *55*(2), 163–176. https://doi.org/10.1016/S0148-2963(00)00152-1

Frazier, W. E. (2014). Metal additive manufacturing: A review. *Journal of Materials Engineering and Performance*, *23*(6), 1917–1928. https://doi.org/10.1007/s11665-014-0958-z

Gao, W., Zhang, Y., Ramanujan, D., Ramani, K., Chen, Y., Williams, C. B., … Zavattieri, P. D. (2015). The status, challenges, and future of additive manufacturing in engineering. *Computer-Aided Design*, *69*(March 2016), 65–89. https://doi.org/10.1016/j.cad.2015.04.001

Gatignon, H., & Robertson, T. S. (1989). Technology Diffusion: an Empirical Test of Competitive Effects. *Journal of Marketing*, *53*(1), 35–49. https://doi.org/10.2307/1251523

Grover, V. (1993). An Empirically Derived Model for the Adoption of Customer-based Interorganizational Systems. *Decision Sciences*, *24*(3), 603–640. https://doi.org/10.1111/j.1540-5915.1993.tb01295.x

Hammann, P. (1979). Personal Selling. *European Journal of Marketing*, *13*(6), 141–176. https://doi.org/10.1108/09574090910954864

Harris, I. D. (2011). Development and Implementation of Metals Additive Manufacturing. *DOT*

International, New Orleans, 1–14.

Hsu, P.-F., Kraemer, K., & Dunkle, D. (2006). Determinants of E-Business Use in U.S. Firms. *International Journal of Electronic Commerce*, *10*(4), 9–45. https://doi.org/10.2753/JEC1086-4415100401

Huang, Y., Leu, M. C., Mazumder, J., & Donmez, A. (2015). Additive Manufacturing: Current State, Future Potential, Gaps and Needs, and Recommendations. *Journal of Manufacturing Science and Engineering*, *137*(1), 1–10. https://doi.org/10.1115/1.4028725

Iacovou, C. L., Benbasat, I., & Dexter, A. S. (1995). Electronic Data Interchange and Small Organizations: Adoption and Impact of Technology. *MIS Quarterly*, *19*(4), 465–485. https://doi.org/10.2307/249629

Industrial Laser Solutions Editors. (2016). Additive manufacturing material enables Airbus to design lightweight aircraft parts. Retrieved June 19, 2017, from http://www.industrial-lasers.com/articles/2016/11/additive-manufacturing-material-enables-airbus-to-design-lightweight-aircraft-parts.html

Johnston, W. J., & Lewin, J. E. (1996). Organizational buying behavior: Toward an integrative framework. *Journal of Business Research*, *35*(1), 1–15. https://doi.org/10.1016/0148-2963(94)00077-8

Kai-ming Au, A., & Enderwick, P. (2000). A cognitive model on attitude towards technology adoption. *Journal of Managerial Psychology*, *15*(4), 266–282. https://doi.org/10.1108/02683940010330957

Kianian, B., Tavassoli, S., Larsson, T. C., & Diegel, O. (2015). The Adoption of Additive Manufacturing Technology in Sweden. *3D Printing and Additive Manufacturing*, *2*(4), 152–158. https://doi.org/10.1016/j.procir.2016.01.036

Kietzmann, J., Pitt, L., & Berthon, P. (2015). Disruptions, decisions, and destinations: Enter the age of 3-D printing and additive manufacturing. *Business Horizons*, *58*(2), 209–215. https://doi.org/10.1016/j.bushor.2014.11.005

Kuan, K. K. Y., & Chau, P. Y. K. (2001). A perception-based model for EDI adoption in small businesses using a technology-organization-environment framework. *Information and Management*, *38*(8), 507–521. https://doi.org/10.1016/S0378-7206(01)00073-8

Lee, C.-P., & Shim, J. P. (2007). An Exploratory Study of Radio Frequency Identification (RFID) Adoption in the Healthcare Industry. *European Journal of Information Systems*, *16*(6), 712–724. https://doi.org/10.1057/palgrave.ejis.3000716

Lewis, W., Agarwal, R., & Sambamurthy, V. (2003a). Sources of Influence on Beliefs about Information Technology Use: An Empirical Study of Knowledge Workers. *MIS Quarterly*, *27*(4), 657–678.

Lewis, W., Agarwal, R., & Sambamurthy, V. (2003b). Sources of Influence on Beliefs about Information Technology Use: An Empirical Study of Knowledge Workers. *MIS Quarterly*, *27*(4), 657–678. https://doi.org/10.2307/4132321

Mellor, S., Hao, L., & Zhang, D. (2014). Additive manufacturing: A framework for implementation. *International Journal of Production Economics*, *149*, 194–201. https://doi.org/10.1016/j.ijpe.2013.07.008

Mishra, A. N., Konana, P., & Barua, A. (2007). Antecedents and consequences of Internet use in procurement: An empirical investigation of U.S. manufacturing firms. *Information Systems Research*, *18*(1), 103–120. https://doi.org/10.1287/isre.1070.0115

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192–222. https://doi.org/10.1287/isre.2.3.192

Nelson, R. R., & Winter, S. G. (2009). *An evolutionary theory of economic change*. Harvard University Press.

Nohria, N., & Gulati, R. (1996). Is Slack Good or Bad for Innovation? *Academy of Management*, *39*(5), 1245–1264. https://doi.org/10.5465/AMJ.1962.5065118

Oliveira, T., & Martins, M. (2011). Literature review of Information Technology Adoption Models at Firm Level. *Electronic Journal of Information Systems Evaluation*, *14*(1), 110–121. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=15666379&AN=65267826&h=+3mBLgsH44TuP+Md6aBOWR03issM0HLuIC10e2bYsd573ACXyFRydASKNeJIVclRbeOPZqZtJv6cXzNTjE4tdA==&crl=c

Park, Y., & Chen, J. V. (2007). Acceptance and adoption of the innovative use of smartphone. *Industrial Management & Data Systems*, *107*(9), 1349–1365. https://doi.org/10.1108/02635570710834009

Premkumar, G., & Ramamurthy, K. (1995). The Role of Interorganizational and Organizational Factors on the Decision Mode for Adoption of Interorganizational Systems. *Decision Sciences*, *26*(3), 303–336. https://doi.org/10.1111/j.1540-5915.1995.tb01431.x

PwC & Manufacturing Institute. (2016). 3D Printing comes of age in US industrial manufacturing. Retrieved November 29, 2016, from http://www.pwc.com/us/en/industrial-products/publications/assets/pwc-next-manufacturing-3d-printing-comes-of-age.pdf

Rayna, T., & Striukova, L. (2016). From rapid prototyping to home fabrication: How 3D printing is changing business model innovation. *Technological Forecasting and Social Change*, *102*, 214–224. https://doi.org/10.1016/j.techfore.2015.07.023

Richard D'Aveni. (2015). The 3-D Printing Revolution. Retrieved June 20, 2017, from https://hbr.org/2015/05/the-3-d-printing-revolution

Robinson, P. J., Faris, C. W., & Wind, Y. (1967). *Industrial Buying and Creative Marketing*. Boston: Allyn & Bacon.

Rogers, E. M. (2003). *Diffusion of Innovations* (Third Edit). New York: Free Press.

Seifi, M., Salem, A., Beuth, J., Harrysson, O., & Lewandowski, J. J. (2016). Overview of Materials Qualification Needs for Metal Additive Manufacturing. *Jom*, *68*(3), 747–764. https://doi.org/10.1007/s11837-015-1810-0

Sheth, J. N. (1973). A Model of Industrial Buyer Behavior. *Journal of Marketing*, *37*(4), 50. https://doi.org/10.2307/1250358

Simonot, A., Cassaignau, A., & Coré-Baillais, M. (2015). *The State of 3D Printing*. *Additive Manufacturing*. Retrieved from http://www.sculpteo.com/static/0.30.0-62/download/report/Sculpteo_State_of_3D_Printing.pdf

SmarTech Markets Publishing LLC. (2017). *Additive Manufacturing with Metal Powders 2017: An Opportunity Analysis and Ten-Year Forecast*.

Talukder, M. (2012). Factors affecting the adoption of technological innovation by individual employees: An Australian study. *Procedia - Social and Behavioral Sciences*, *40*, 52–57. https://doi.org/10.1016/j.sbspro.2012.03.160

Thomas, D., & Gilbert, S. (2014). Costs and Cost Effectiveness of Additive Manufacturing - A Literature Review and Discussion. *NIST Special Publication*, *1176*, 1–77. https://doi.org/10.6028/NIST.SP.1176

Thong, J. Y. L. L. (1999). An integrated model of information systems adoption in small businesses. *Journal of Management Information Systems*, *15*(4), 187–214. https://doi.org/10.2307/40398410

Tolbert, P. S., & Zucker, L. G. (1983). Institutional Sources of Change in the Formal Structure of Organizations: The Diffusion of Civil Service Reform, 1880-1935. *Administrative Science Quarterly*, *28*(1), 22–39. https://doi.org/10.2307/2392383

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *The processes of technological innovation*. Lexington: Lexington Books.

Tornatzky, L. G., & Klein, K. J. (1982). Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, *29*(1), 28–45. https://doi.org/10.1109/TEM.1982.6447463

Tushman, M., & Nadler, D. (1986). Organizing for Innovation. *California Management Review1*, *XXVIII*(3), 74–92.

Van Der Sijde, P., Van Reekum, R., Jeurissen, W., & Rosendaal, B. (2015). To Adopt or Not to Adopt? The RFID Adoption Consideration by Entrepreneurs in a Purchasing Cooperative in Dutch Book Retailing. *International Journal of Innovation and Technology Management*, *12*(1), 1–20. https://doi.org/10.1142/S0219877015500066

van Everdingen, Y., van Hillegersberg, J., & Waarts, E. (2000). Enterprise resource planning: ERP adoption by European midsize companies. *Communications of the ACM*, *43*(4), 27–31. https://doi.org/10.1145/332051.332064

Vartanian, K., & McDonald, T. (2016). Accelerating Industrial Adoption of Metal Additive Manufacturing Technology. *Jom*, *68*(3), 806–810. https://doi.org/10.1007/s11837-015-1794-9

Waarts, E., Van Everdingen, Y. M., & Van Hillegersberg, J. (2002). The dynamics of factors affecting the adoption of innovations. *Journal of Product Innovation Management*. https://doi.org/10.1016/S0737-6782(02)00175-3

Wang, J.-C., & Tsai, K.-H. (2002). Factors in Taiwanese firms' decisions to adopt electronic commerce: An empirical study. *World Economy*, *25*(8), 1145–1167. https://doi.org/10.1111/1467-9701.00486

Wang, Y. M., Wang, Y. S., & Yang, Y. F. (2010). Understanding the determinants of RFID adoption in the manufacturing industry. *Technological Forecasting and Social Change*, *77*(5), 803–815. https://doi.org/10.1016/j.techfore.2010.03.006

Webster, F. E., & Wind, Y. (1972). A General Model for Understanding Organization Buying Behavior. *Journal of Marketing*, *36*(2), 12–19.

Wohlers, T., & Caffrey, T. (2016). *Wohlers Report 2016*.

Zhu, K., Kraemer, K. L., & Xu, S. (2006). The Process of Innovation Assimilation by Firms in Different Countries: A Technology Diffusion Perspective on E-Business. *Management Science*, *52*(10), 1557–1576. https://doi.org/10.1287/mnsc.1050.0487

Zhu, K., Kraemer, K., & Xu, S. (2003). Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors. *European Journal of Information Systems*, *12*(4), 251–268. https://doi.org/10.1057/palgrave.ejis.3000475