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The Diffusion of Additive Manufacturing in the Medical Industry

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Abstract

Background: There has been a recent hype regarding three-dimensional printing (3DP) and additive manufacturing (AM). Especially the medical industry is often seen as a field for successful AM applications, producing customized products. Yet, it is not clear whether this hype is based on real developments, or on an unfounded surge in media interest. At the same time, studies on AM do not attempt to assess whether it is going to be diffused, but preempt that it will be. Consequently, there is a lack of knowledge about the diffusion of AM. Studies on diffusion are limited by mostly taking an individual stakeholder perspective, even though the context of the innovation affects its diffusion. Therefore, studies from a systemic perspective are needed to accurately analyze diffusion.

Purpose: The purpose of the study is to examine the diffusion of AM in the medical industry through the lens of diffusion of innovations theory and answer two research questions: *What are the factors influencing the diffusion of additive manufacturing in the medical industry? How do these factors affect the diffusion?*

Method: To study diffusion in a clearly circumscribed system, the Swedish medical industry is used as a case study object. The study employs an exploratory, qualitative research design with the help of semi-structured interviews. Propositions are made to place limits on the study's scope and increase its feasibility. Those are tested against empirical data that was gathered in 30 interviews with various stakeholders from academia, industry and government. The subsequent analysis is carried out based on coding and thematic analysis.

Conclusion: The social system and the innovation's attributes together clearly affect the diffusion of AM in the medical industry. AM's relative advantage and trialability affect the diffusion positively, whereas its observability, compatibility, complexity and re-invention have a negative effect. Physicians as opinion leaders, the weak network structures of the Swedish medical industry and the high levels of authoritative decision-making each have a negative effect on diffusion. The usage of interpersonal communication has a positive effect on diffusion. Additionally, three interrelations between factors are found: the complexity of an innovation affects the use of communication channels, the actions of opinion leaders and change agents are found to affect social structure and innovation-decisions have an effect on the observability.

Contribution: The study underpins the need for a systemic view, when analyzing diffusion. It clarifies that studies of single factors are not accurate enough to explain diffusion, as interrelations between the social system's factors and the innovation's factors have been found. Additionally, it expands on the initial diffusion of innovations framework, by adding the factor re-invention which affects how potential adopters perceive the innovation.

Key words: Diffusion of innovations, additive manufacturing, 3D printing, medical industry, social system.

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Christopher Sabel and Mikolaj Gruszczynski

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Definition of Key Concepts

Diffusion of Innovations

"[…] *the process in which an innovation is communicated through certain channels over time among the members of a social system.*" (Rogers, 2003, p. 5)

Additive Manufacturing

"The process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining." (ASTM Standard 2792 - 12a, 2012)

The medical industry

"The medical, or healthcare industry, encompasses the complex of preventive, remedial, and therapeutic services provided by hospitals and other institutions, nurses, doctors, dentists, medical administrators, government agencies, voluntary agencies, non-institutional care facilities, pharmaceutical and medical equipment manufacturers, and health insurance companies." (Mosby, 2008)

List of Abbreviations

3DP	3-Dimensional Printing
AM	Additive Manufacturing
CAD	Computer-Aided Design
CM	Conventional Manufacturing
CT	Computed Tomography
DMU	Decision Making Unit
EU	European Union
FDA	Food and Drug Administration
HTA	Health Technology Assessment
MRT	Magnetic Resonance Tomography
OECD	Organization for Economic Co-operation and Development
PPP	Public Private Partnership
RM	Rapid Manufacturing
RP	Rapid Prototyping
RT	Rapid Tooling
WHO	World Health Organization

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1. Introduction

The first chapter gives an overview of the topic (1.1), highlighting its managerial (1.2) and theoretical relevance (1.3), before the research question is introduced (1.4). Subsequently, the chapter rounds off with the outline of the thesis (1.5).

1.1 Background Information

There has been a recent increase in interest regarding three-dimensional printing (3DP) and additive manufacturing (AM) among the public, companies and scholars alike. Despite the origin of those technologies dating back to the early 1980s, public interest just recently jumped, following the possibility for customized production of consumer goods (Dempski and Webb, 2013; Hague and Reeves, 2013). Media, often claims that AM is going to become transformative for today's societies (Hague and Reeves, 2013). The Economist (2012) even called 3DP the "third industrial revolution", comparing it to the first industrial revolution in the 18th century's textile industry. Likewise, industry numbers show a positive trend as the primary AM market, which encompasses all AM systems, material sales and associated services globally, grew from \$2.3 billion in 2012 by 34.9% to \$3.07 billion in 2013. AM growth has been tremendous with a compound annual growth rate of 30.3% from 2010 to 2013 underpinning the recent hype (Wohlers, 2014). At the same time, while media sees enormous developments in the approaching breakthrough for AM (Mellor, Hao and Zhang, 2014), Hague and Reeves (2013) argue that media coverage is often overstating AM's current possibilities and technological readiness. Indeed, in 2011, AM just accounted for 0.01% of US manufacturing, whereas 38.3% of global machines had been installed in the US (Ford, 2014). Therefore, the recent interest does not seem to be based on industrial developments, but rather on consumer applications raising awareness through media (Dempski and Webb, 2013; Hague and Reeves, 2013). In general, new technologies are often accompanied by cycles of hype and disappointment where advocates of technologies promote a mostly positive outlook on the technology's potential (Fox, 2013).

Advocates of AM claim that the hype is justified, as AM's focus changed from prototyping and tooling towards the production of functional end user parts (Goodridge, Tuck and Hague, 2012; Hague and Reeves, 2013; Mellor et al., 2014). Even though prototyping and tooling are still important, functional parts already account for 29%, the largest part of the market (Wohlers, 2014). Especially the demand for customized products increases the incentive to use AM (Eyers and Dotchev, 2010). According to Wohlers (2014), AM is used mostly for the production of industrial machines (18.5%), consumer products (18%), motor vehicles (17.3%), medical and dental goods (13.7%), as well as aerospace equipment (12.3%).

Based on those numbers, the medical industry is often seen as successful industrial AM application, producing customized medical products (Berman, 2012). Multiple products such as hearing aids, dental crowns, artificial limbs and implants are demanded additively manufactured (Goodridge et al., 2012; Hague and Reeves, 2013; Huang, Liu, Mokasdar and Hou, 2013; Mellor et al., 2014; Zhai, Lados and Lagoy, 2014). Those are especially well suited for AM, as medically scanned data from CT and MRT can be easily transformed to computer-aided-design (CAD) files, creating an exact model of the patient's physiology and the medical device needed. This improved customization increases the product's quality for the patient, as customized devices reduce patient discomfort and stress for the body (Campbell, Bourell and Gibson, 2012; Hague and Reeves, 2013; Huang et al., 2013). Based on that, it is established that AM has a positive effect on quality of care for patients and enables delivery of a higher-quality care, with healthcare products customized to the individual's needs ((Bibb, Eggbeer and Williams, 2006; Poukens et al., 2008; Sercombe, Jones, Day and Kop, 2008; Subburaj, Nair, Rajesh and Ravi, 2007).

Up to date, despite the relevance for AM in the medical industry, it has not been researched what the factors for the diffusion of AM in the medical industry are. It is not clear how AM's attributes are affecting its diffusion and what role the medical industry's environment plays as context factor. To analyze the diffusion of AM in the medical industry, diffusion of innovations theory has been used in this study. Here, five main factors are relevant for the diffusion of innovations: (1) the perceived attributes of the innovation, (2) the channels used to communicate it, (3) the structure and norms of the social system it is diffused in, (4) the effect of opinion leaders and change agents, as well as (5) how innovation-decisions are made (Rogers, 2003; Tidd, 2010; Wolfe, 1994).

1.2 Managerial Relevance

Apart from AM's potential, there is a general pressure in the medical industry to utilize new technologies. Governments around the world are under pressure to balance limited health care budgets against their mandate to guarantee public availability of new medical technologies. Technology evaluations have to account for health-related and economic criteria, explaining pricing decisions, as well as the availability of medical technology. This becomes increasingly crucial as a wider range of medical options is available (Ciurana, 2014; Mehmood Birchall Shah, Barron, Klinger and Wright, 2014). Stakeholders in the medical industry have a dual mandate to improve the quality of care, while decreasing its costs at the same time. Simultaneously, medical device companies are facing new challenges with tightly controlled public healthcare spending and growing demands on treatment efficiency and personalized treatments. To cope with those challenges and improve products and services, companies have to build capabilities for innovation (Nilsson, 2012). Given this pressure on government stakeholders, as well as medical device companies and the relevance of quality of care for the public, the adoption of AM becomes an increasingly relevant option. However, technology adoption in the medical industry is a poorly understood phenomenon, as there is a strong variation in the acceptance of technological innovation among health care providers (Angst, Agarwal, Sambamurthy and Kelley, 2010). Consequently, research on the diffusion of innovations is highly relevant for multiple stakeholders such as governments and medical device companies, as it can explain why certain technologies are adopted or rejected.

1.3 Theoretical Relevance

Research on AM is not carried out through the lens of diffusion, but mainly from a medical or technological point of view. Medical scholars are not focusing on factors affecting AM's diffusion. Here, studies are either focusing on feasibility of applications years away from maturity like biomedical tissue-engineering, or on technological reaffirmation of applications that are already on the market for years, such as dental crowns or braces (Tuomi et al., 2014). The few medical studies that research non-application-related issues focus on individual stakeholders' roles in their development. Thereby, multiple reasons for AM's development, such as the physicians' relatively low propensity to innovate or the slow approval process for medical devices, are found (Campbell et al., 2012). Manufacturing research focuses on the technical side, illustrating innovation-related barriers for the diffusion of AM, like narrow material range, high machine and material costs, lack of technical standards and designs, as well as relatively low process speeds (Hague and Reeves, 2013; Mellor et al., 2014). However, those studies are limiting possible factors for AM's diffusion to technological attributes, neglecting differences in the environment it is diffused in. Yet, research clearly shows that an innovation's context, affects its diffusion (Rogers, 2003; Tidd, 2010; Wolfe, 1994).

In general, management scholars begin to engage in the research of AM and possible consequences of companies' adoption. However, the focus lies on operations management and how AM has the potential to shorten traditional supply chains (Mellor et al., 2014; Holmström, Partanen, Tuomi, and Walter, 2010; Huang et al., 2013; Tuck, Hague and Burns, 2007). Otherwise only scattered research about impacts on intellectual property rights (Appleyard, 2015; Hague and Reeves, 2013; Kilkenny, 2014) and impacts on industrial waste and sustainability exists (Diegel, Singamneni, Reay and Withell, 2010; Hague and Reeves, 2013). Yet, all those studies anticipate a successful diffusion of AM. According to the authors' knowledge, there is no study from a managerial point of view that actually tries to assess the factors limiting or favoring the diffusion of AM.

To study the factors influencing the diffusion of AM and expand on the general knowledge about diffusion, the theoretical concept of diffusion of innovations is tested. The study adds knowledge to the diffusion of innovations, as it is poorly understood and under-researched from a systemic point of view. From a systemic perspective all factors that affect the diffusion of an innovation in a social system have to be taken into account. These factors encompass communication channels, system structure and norms, opinion leader's and change agent's roles, as well as the process of decision-making of the system as a whole (Rogers, 2003; Tidd, 2010; Wolfe, 1994). Most studies focus only on single factors such as the innovation itself or opinion leaders' role in the diffusion, even though technology adoption depends to a great extent on systemic factors. In fact around 60% of diffusion studies focus on the individual innovativeness of the potential adopter (Rogers, 2003; Tidd, 2010). To overcome this limitation, not only the perceived technological attributes of additive manufacturing are examined, but also the factors inherent to the social system, which AM is diffused in.

1.4 The Research Question

The study examines at the diffusion of AM in a clearly circumscribed system, the medical industry. This adds to the knowledge of diffusion, as it shows all factors' effects in their context (Figure 1).

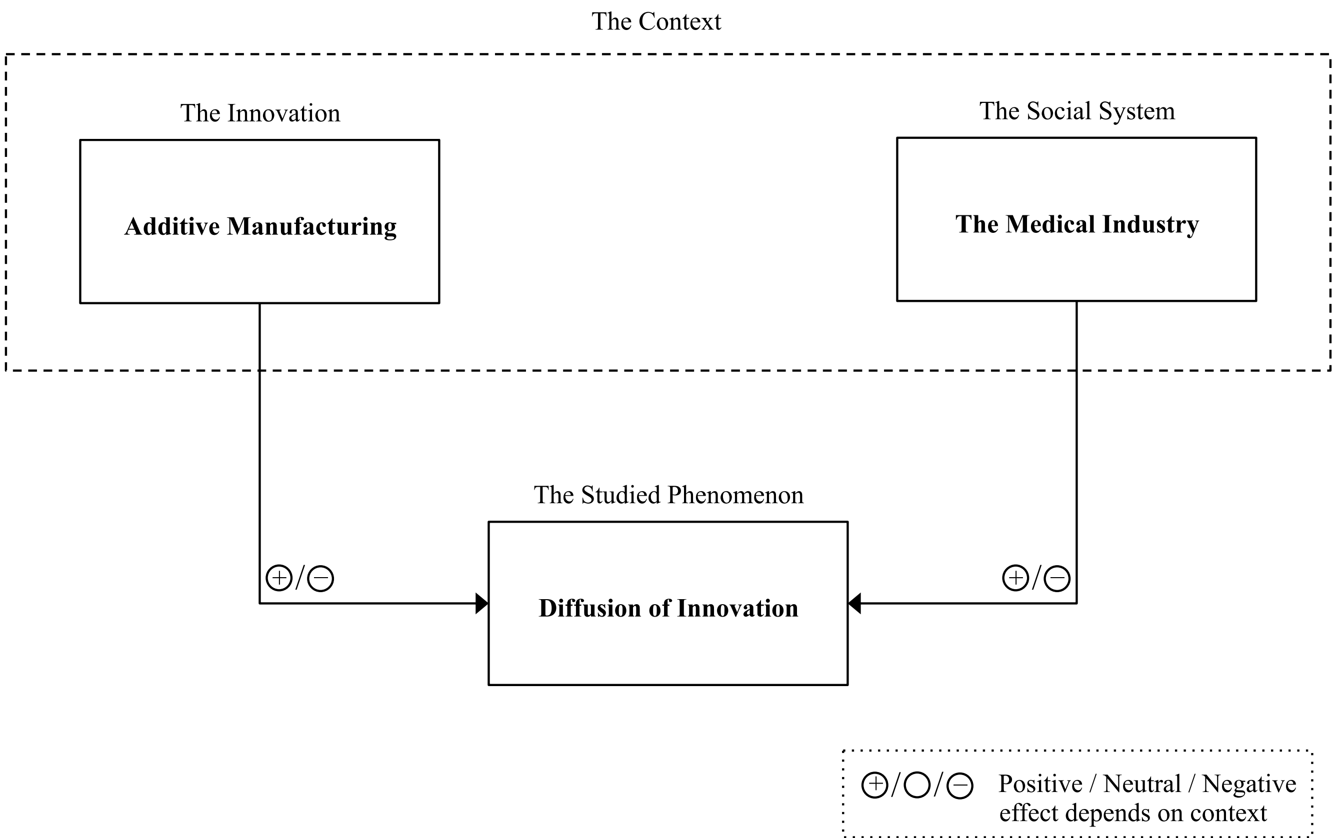

Figure 1: Research Gap

Based on this rationale, the guiding research questions are:

> *What are the factors influencing the diffusion of additive manufacturing in the medical industry?*
>
> *How do these factors affect the diffusion?*

To answer the first question, a qualitative examination of the presence of the factors influencing the diffusion of innovations needs to be carried out. To answer the second question, an analysis on the effects of these factors on AM's diffusion needs to be executed. Hereby, it is analyzed whether the aforementioned factors affect AM's diffusion negatively or positively.

1.5 Outline of the Paper

The paper's structure in mirrored chapters emphasizes the level of analysis and creates an hourglass-like approach (Hill, Soppelsa and West, 1982; Swales, 1990) (Figure 2).

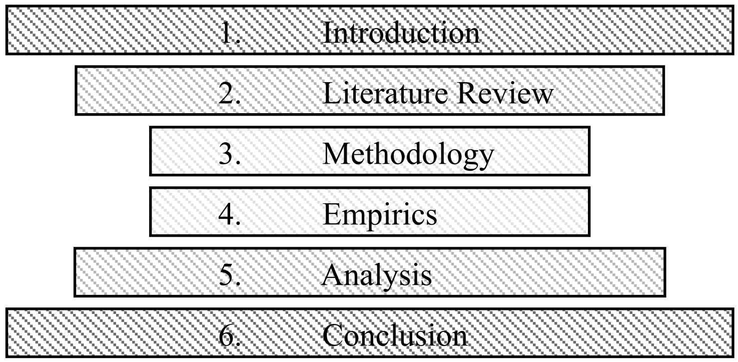

Figure 2: Structure of the Paper

The introduction (1) illustrates AM's potential, issues in research and the relevance of the research question. In the literature review (2) the theoretical frame of diffusion of innovations is investigated more in detail. Within that, additive manufacturing, as well as the medical industry are related to diffusion theory to make the intersection visible. The literature review closes with the demonstration of the theoretical gap and the theoretical framework used. Afterwards, the methodology (3) is presented, including research design, data collection, documentation and analysis. The methodology ends with a critical review of the study's reliability, validity and limitations. Hereupon, the findings of the case study are presented in the empirical results (4) and explained according to the theoretical framework. In the main part of the paper, the analysis (5), findings are examined and implications are drawn. To conclude the paper (6), theoretical and managerial relevance of the results are put into context, the research question is answered and recommendations for potential further studies are given.

2. Literature Review

The chapter starts with the theoretical concept of diffusion of innovations (2.1) introduces the innovation's perceived attributes (2.2), and the social system's factors (2.3). Subsequently, the research gap is highlighted (2.4), before the theoretical framework is developed, relating theory to additive manufacturing and the medical industry (2.5).

2.1 The Diffusion of Innovations

Broad adoption of an innovation can take years, even when it is obviously superior to the previous method. Such lengthy processes cost time and resources and thus make it necessary to find means to speed up the process of diffusion for organizations (Rogers, 2003). After integrating hundreds of studies from different scientific fields (Dekimpe, Parker and Sarvary, 2000), Everett Rogers (2003, p. 5) the most prominent researcher in the field of diffusion defines diffusion as:

> *"[…] the process in which an innovation is communicated through certain channels over time among the members of a social system".*

Given this definition, diffusion is a process of communication about an innovation that alters social systems (MacVaugh and Schiavone, 2010; Rogers, 2003; Tidd, 2010). There are multiple classifications for innovations, highlighting different aspects of the concept. Different dimensions, such as novelty of the innovation (incremental – radical), affected parts of the value chain (component – architecture) and innovation area (product – process) can all vary between different explanatory approaches (Angst et al., 2010; Rowley, Baregheh and Sambrook, 2011; Tidd and Bessant, 2007). The dimensions all address different aspects of innovation. The diffusion of innovations theory does not highlight the different dimensions, but focuses on the one aspect all have in common, their innate uncertainty and risk for managers in case of adoption (Angst et al., 2010). For the research of diffusion, an innovation has to be perceived as new by an individual or other unit of adoption (e.g. informal group, organization). Not the objective novelty is crucial, but whether it is new for the unit of adoption that is introduced to it. Novelty does not imply ignorance of existence, but it suffices that the individual did not develop an opinion about that innovation (Rogers, 2003).

The spatial part of the definition refers to the social system. A social system is defined as a set of interrelated units engaging in joint problem solving to accomplish a common goal. Members of a social system can be individuals, groups, organizations or subsystems. The lowest common denominator is that all members cooperate, aspiring to solve a common problem, in order to reach a common goal. This shared objective links the system. Diffusion of innovations occurs within a social system and constitutes the boundaries of diffusion. Within the system, social structure, norms, opinion leaders, change agents and innovation-decisions affect the diffusion (Greenhalgh, Robert, MacFarlane, Bate and Kyriakidou, 2004; Rogers, 2003). Diffusion in a social system can be measured by the rate of adoption, which measures the number of a system's members that adopt the innovation in a given time period. The system perspective is especially relevant, as variations in an innovation's rate of adoption in different social systems can be seen (Mahajan, Muller and Bass, 1995; Mahajan, Muller and Srivastava, 1990).

To make this rather abstract concept of how an innovation diffuses in a social system more tangible, the factors influencing the diffusion of innovations are explained in detail in the subsequent chapter. Through an accumulation of diffusion studies throughout the 20th century Rogers (2003) found that the perceived attributes of the innovation (2.2.1) as well as the social system (2.2.2) are the most important factors influencing the diffusion of innovations. Those factors have been confirmed and restudied by multiple other authors (Tidd, 2010).

2.2 Perceived Attributes of the Innovation

The innate attributes of an innovation greatly affect its diffusion, whereas research agrees that five attributes are most important for diffusion: (1) Relative advantage, (2) trialability, (3) observability, (4) complexity and (5) compatibility (Greenhalgh, Robert, MacFarlane, Bate and Kyriakidou, 2004; Rogers, 2003; Tidd, 2010; Wolfe, 1994).

2.2.1 Relative Advantage

Relative advantage is the extent to which an innovation is perceived as superior to the predecessor it replaces. This can be specified through various characteristics such as economic terms, social prestige or satisfaction levels. Here, the objective advantage, as well as the perceived advantage have to be considered. The greater the perceived relative advantage of an innovation is, the more rapid its rate of adoption (Baptista, 2001; Rogers, 2003). If potential adopters do not see any relative advantage, they generally do not consider it for adoption. Consequently, relative advantage is also the most important factor (Greenhalgh et al., 2004). Switching costs also have to be taken into account, as lock-in effects and the emergence of industry standards can decrease advantages and make adoption of a new technology more unlikely (MacVaugh and Schiavone, 2010). Many studies have shown positive effects of relative advantage. These include added functionality in surgical technologies (Dirksen, Ament and Go, 1996), improved information accessibility in digital patient cards in hospitals (Aubert and Hamel, 2001), and relative price advantages in consumer electronics (Rosen, 2000).

2.2.2 Trialability

Trialability is the extent to which an innovation can be experimented with. Thereby, experimentation helps to decrease the uncertainty regarding the innovation and raises the rate of adoption (Greenhalgh et al., 2004; Rogers, 2003; Tidd, 2010). Studies show that trialability has a positive effect on diffusion. Increased participation rate of addicts in substance abuse programs after trials (Ducharme, Knudsen, Roman and Johnson, 2007) and customer increase after try-out phases for online banking (Chaipoopirutana, Combs, Chatchawanwan and Vij, 2009) are just some of them.

2.2.3 Observability

Observability refers to the extent to which the outcome of an innovation's adoption is visible to other potential adopters. The higher the visibility of an innovation's adoption, the faster it will be adopted by others (Denis, Herbert, Langley, Lozeau and Trottier, 2002; Greenhalgh et al., 2004; Rogers, 2003). Studies show that perceived patient success in health programs is a major factor in adoption for other patients (Scott, Plotnikoff, Karunamuni, Bize and Rodgers, 2008), and the visible adoption of personal computers increases adoption among peers (Al-Gahtani, 2003).

2.2.4 Complexity

Complexity is defined as the extent to which an innovation is perceived as difficult to understand and use. The diffusion of an innovation is slower when new skills or knowledge are needed for its adoption (Denis et al., 2002; Greenhalgh et al., 2004; Rogers, 2003; Tidd, 2010). In fact, multiple studies have shown that high complexity affects the adoption of an innovation negatively, as in the cases of diesel engines in fisher boats (Sinde-Cantorna, Alvarez-Llorente and Dieguez-Castrillon, 2013), or clinical practice guidelines (Grilli and Lomas, 1994).

2.2.5 Compatibility

Compatibility is the extent to which an innovation is perceived as corresponding with existing values, experiences and needs of potential adopters. An incompatible innovation will not be adopted as fast as a compatible one, as it frequently demands changes in values of potential adopters (Denis et al., 2002; Greenhalgh et al., 2004). One can also distinguish between compatibility with existing practices and compatibility with values, the latter being more important for successful adoption (Leonard-Barton and Sinha, 1993). Here, several studies show that technology innovations have the effect of changing work roles, social networks and power relations, thereby fostering uncertainty among adopters and decreasing their willingness to adopt (Barley, 1990; Compagni, Mele and Ravasi, 2015).

Nevertheless, it is not sufficient for an innovation to only have those attributes; it also has to reach potential adopters. To highlight where the perceived attributes of an innovation are diffused factors inherent to the social system are illustrated below.

2.3 The Social System

The social system is encompassing communication channels (2.3.1), social structure and system norms (2.3.2), opinion leaders and change agents (2.3.3) and innovation-decisions (2.3.4).

2.3.1 Communication Channels

Communication is defined as the process by which participants mutually create and share information to reach a common understanding. The communication process for the diffusion of innovations encompasses: An innovation, a unit of adoption that knows about the innovation or uses it, a unit of adoption that does not yet have any knowledge or opinion about the innovation and finally a communication channel connecting them (Rogers, 2003; Tidd, 2010). Channels can differ from mass media to interpersonal communication. Mass media are often the fastest and efficient ways to inform potential adopters about the availability of an innovation (awareness knowledge), as they can simultaneously reach a great audience. However, interpersonal channels such as face-to-face communication are effective in the persuasion of potential adopters to accept an innovation (Baptista, 2001; Roman, 2003; Rogers, 2003). This can be explained by individuals' tendency to rely on subjective appraisal of peers who have already adopted an innovation, rather than on objective judgment (Rogers, 2003). Valente (1996) restudied empirical results of diffusion studies about medical innovations, farmers' adoption of hybrid corn and family planning. He found that while external channels such as media, campaigns and targeted literature create awareness, interpersonal influence with socially close individuals such as friends and neighbors are what lead to actual adoption. Therefore, the increased use of interpersonal channels is expected to have a positive effect on diffusion.

Communication about innovations happens most often between people who are similar in characteristics such as socioeconomic status and education. The communication of ideas is effective among people similar in individual and social attributes, as attitude formation and knowledge gain is more likely (Rogers, 2003). Therefore, since social structure and system norms are important in shaping personal attributes, they are scrutinized.

2.3.2 Social Structure and System Norms

Social structure is defined as the structured arrangements of the actors in systems that give them regularity and stability and make human behavior predictable to some extent. Structure represents a form of information that decreases uncertainty. The formal structure of the social system represents the hierarchy of social relationships being described by the status of single members in the system (MacVaugh and Schiavone, 2010; Rogers, 2003). The informal structure is given by interpersonal networks that describe who interacts with whom and under which circumstances. There is most probably a communication structure visible, as an absence would indicate that each person in a system is equally likely to interact with everyone else in this system. However, as introduced before, the similarity of individuals affects with whom they socialize. Consequently, structure can affect the diffusion of innovations (Fitzgerald, Ferlie, Wood and Hawkins, 2002; Greenhalgh et al., 2004).

In addition to the structure there are social norms that represent established behavior standards for the members of a social system. Norms determine a spectrum of acceptable behaviors and serve as guide for the members of the social system. Also, norms form expectations and can manifest on various levels such as countries, religions, communities or organizations (Rogers, 2003; Tidd, 2010). As adopters influence others over time, diffusion is a "temporal process of social contagion" (Angst et al., 2010, p. 1220) or so-called bandwagon process of reciprocal contagion (MacVaugh and Schiavone, 2010; Tidd, 2010). Hence, potential adopters often imitate their peers and the higher the similarity between potential adopters, the more innovation diffusion becomes likely (Fitzgerald et al., 2002; Greenhalgh et al., 2004).

Nevertheless, even though there are forces for normative behavior in a social system, there are certain members and externals that can influence behaviors of others, namely opinion leaders and change agents.

2.3.3 Opinion Leaders and Change Agents

The most innovative members of a social system are often seen as deviants from the system and have therefore low credibility with the average members. Thus, their role in diffusion and their persuasiveness are very limited. Others act as opinion leaders in the system, providing information and evaluations about innovations to other members. Opinion leader's effectiveness refers to the extent and frequency of their informal influence on other members' attitudes and behavior. However, it does not stem from the individual's formal position or status (Fitzgerald et al, 2002; Greenhalgh et al., 2004; Rogers, 2003). Opinion leadership is accumulated and sustained through technical competence, social accessibility and conformity to the systems norms. Consequently, opinion leaders reflect the system's norms and structure and act as models for the innovation behavior of other members. However, compared to other members, they are more exposed to external communication, often have higher socioeconomic status and are more innovative. Additionally, they are at the center of the systems communication network, which consists of the interconnected members (Rogers, 2003; Sundstrom, 2014). Multiple studies, such as in a study about diffusion of mental health programs (Atkins et al., 2008) support that opinion leaders can positively affect diffusion.

Another kind of opinion leader is the change agent, who champions interest groups external to the system. Change agents affect members' innovation-decisions as desired by the interest group they represent. The change agent normally advocates the adoption of innovations, but may also try to decelerate diffusion and stop the adoption of unwanted innovations. Furthermore, change agents often contact internal opinion leaders for assistance in their diffusion activities. However, opinion leaders can be worn out by change agents when they are approached to often for assistance, as they lose authenticity with other members and may be perceived as change agents themselves (Rogers, 2003; Sundstrom, 2014). Change agents' efforts are normally positively related to the diffusion of innovations and can be viewed in studies about anti-smoking campaigns promoted by physicians (Korhonen, Uutela, Korhonen, Urjanheimo and Puska, 1999).

After highlighting the actors, context and object of decisions, the process of how innovation decisions are made in a social system is explained.

2.3.4 Innovation-Decisions

The innovation-decision process ranges from first knowledge of an innovation to the confirmation of the decision and encompasses the five steps of (1) knowledge, (2) persuasion, (3) decision, (4) implementation and (5) confirmation. This process focuses on information gathering and processing, whereby a decision making unit (DMU) incrementally decreases uncertainty about the innovation. The length of this process can vary up to multiple years, as this straightforward process is often made by systems of people or organizations and is therefore complex in reality (Fitzgerald et al., 2002; Rogers, 2003). The system perspective shows that multiple stakeholders and the context affect the decision-making process (Fitzgerald et al., 2002; Van de Ven, Polley, Garud and Venkataraman, 1999).

Therefore, innovations can be adopted or rejected by individuals and by the whole social system either collectively or by authority. Innovation-decisions can either positively (adoption) or negatively (rejection) affect diffusion. An optional innovation-decision is made when the decision for adoption or for rejection is made by an individual, such as the decision to purchase a new product. Here, the individual has full responsibility for the decision, but is influenced by the social system, who is often the main DMU (Rogers, 2003). In a collective innovation-decision, the choice to adopt or reject is made through agreement among members of a social system and all members typically have to adjust to the decision. Here each individual can participate in the decision-making process. One example for such a rare kind of decision-making is town halls that collectively decide about changes in their community (Rogers, 2003). The third alternative is the authority innovation-decision, where the choice for rejection or adaption is made by few members of the system who hold power, status or technical expertise. The adopting member does not have a voice in the decision making process (Rogers, 2003). Examples for such decision-making are given by Carter, Jambulingam, Gupta, and Melone (2001) who found that contractual mandates to use an innovation positively affected its diffusion and by Rogers (2003) who describes the increased adoption of car seatbelts after they became obligatory by law.

It can be seen that an authoritative decision often leads to the fastest adoption of an innovation, but it can also significantly block it, in case authorities decide to reject the innovation. Collective decisions are the slowest, as consensus among members of a system has to be reached, which is often not possible in reality (Rogers, 2003).

2.3.5 Integration of the Innovation's and the System's Factors

The study's theoretical framework rests on the factors for diffusion. This framework was chosen, as it builds on Rogers (2003) work, which is considered to be seminal for diffusion research and is the most cited knowledge accumulation for diffusion (Dekimpe et al., 2000; Roman, 2003). The following framework summarizes the above-mentioned factors and their effect on diffusion in a generalized system (Figure 3).

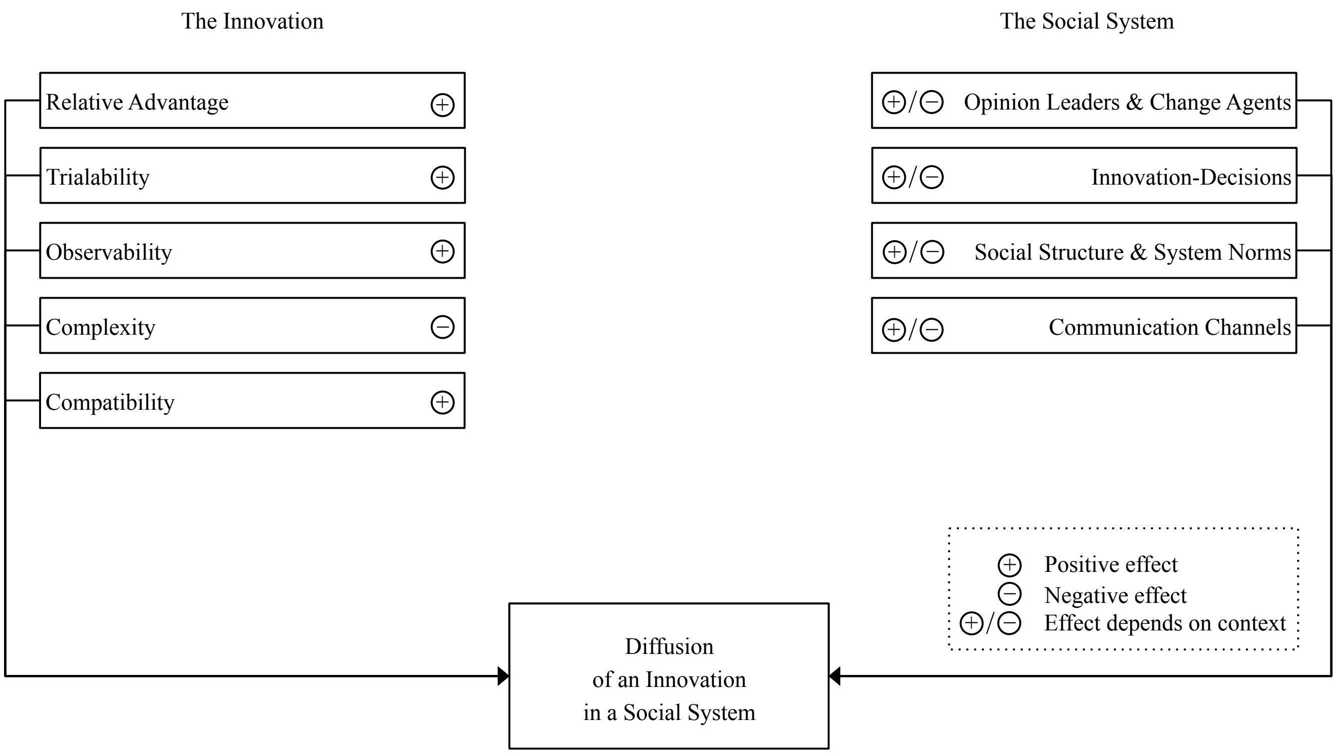

Figure 3: Factors Influencing the Diffusion of Innovations, based on Rogers (2003)

2.4 The Research Gap

Consequently, studies from a systemic perspective are more accurate in analyzing the factors for diffusion. Therefore, this study's approach to look at the diffusion of AM in a clearly circumscribed system, the medical industry, adds to the knowledge of diffusion research, as it shows the effect of all the factors together.

AM has not been researched through the lens of diffusion, but from a technological or medical perspective. Medical researchers are focusing on application-related phenomena, such as the maturity of biomedical technologies or implants (Tuomi et al., 2014), whereas engineering research is focusing on technology-related phenomena like material ranges or process speeds (Hague and Reeves, 2013; Mellor et al., 2014). The few studies in management research that exist are focusing on operations management (Holmström et al., 2010; Tuck, et al., 2007), intellectual property rights (Appleyard, 2015; Kilkenny, 2014) or impacts on sustainability (Diegel et al., 2010; Hague and Reeves, 2013). Those studies are limiting possible factors for AM's diffusion to technological attributes, neglecting differences in the environment it is diffused in. Yet, research clearly shows that an innovation's context, affects its diffusion (Rogers, 2003; Tidd, 2010; Wolfe, 1994). Additional, all those studies anticipate a successful diffusion of AM. According to the authors' knowledge, there is no study from a managerial point of view that actually tries to assess the factors limiting or favoring the diffusion of AM.

In the medical field, studies about the diffusion of drugs, treatments and other medical innovations have a research tradition back to the 1950s (Rogers, 2003). In management science, most diffusion research has been carried out in the marketing field, trying to assess how the marketing mix affects the rate of adoption for new products (MacVaugh and Schiavone, 2010; Rogers, 2003). However, those studies systematize diffusion from a systemic point of view. Single factors are examined isolated even though it is clear that the context influences diffusion. Therefore, conclusive studies about how each factor affects diffusion when they are examined together in their context are lacking (Greenhalgh et al., 2004).

To expand on the knowledge about diffusion of innovations and study the factors influencing the diffusion of AM, the theoretical concept of diffusion of innovations is tested. The study adds knowledge to the diffusion of innovations, as it is poorly understood and under-researched from a systemic point of view. From a systemic perspective all factors that affect the diffusion of an innovation in a social system have to be taken into account. These factors encompass communication channels, system structure and norms, opinion leader's and change agent's roles, as well as the process of decision-making of the system as a whole (Rogers, 2003; Tidd, 2010; Wolfe, 1994). Most studies focus only on single factors such as the innovation itself or opinion leaders' role in the diffusion, even though technology adoption depends to a great extent on systemic factors. In fact around 60% of diffusion studies focus on the individual innovativeness of the potential adopter (Rogers, 2003; Tidd, 2010). To overcome this limitation, not only the perceived technological attributes of additive manufacturing are examined, but also the factors inherent to the social system, which AM is diffused in.

The study looks at the novel technology AM in the medical industry, under-researched from a systemic perspective on diffusion. Based on this rationale, the guiding research questions are:

> *What are the factors influencing the diffusion of additive manufacturing in the medical industry?*
>
> *How do these factors affect the diffusion?*

To answer the first question, a qualitative examination of the presence of the factors influencing the diffusion of innovations needs to be carried out. To answer the second question, an analysis on the effects of these factors on AM's diffusion needs to be executed. Hereby, it is analyzed whether the aforementioned factors affect AM's diffusion negatively or positively.

2.5 The Theoretical Framework

The diffusion of innovations needs to be studied in its specific context (Rogers, 2003; Wolfe, 1994). Therefore, AM is introduced (2.5.1) and examined on its attributes (2.5.2), followed by an introduction and examination of the medical industry's influence (2.5.3). Based on the context's characteristics, the initial framework is adapted, guided by propositions (2.5.4).

2.5.1 Introduction to Additive Manufacturing

The AM-process is very similar for different AM sub-technologies, even though they build in different ways (Campbell et al., 2012). Certain processes use thermal energy from laser or electron beams, which is directed via optics to melt or sinter metal or plastic powder together. Other processes use inkjet-type printing heads to mix binder with powdered ceramics or polymers (Huang et al., 2013). Even though there are many different AM sub-technologies, machines have to be constructed similarly, as the manufacturing process has the same, layered manufacturing concept. Therefore, a common concept of an AM-process can be used, to illustrate it (Brajlih, Valentan, Balic and Drstvensek, 2011).

AM-production follows three mandatory and one optional step. First comes the development of a 3D-CAD model, where a model is either created on a computer or through scanning of an existing object and then converted into a standard AM file format. Secondly, the file is sent to the AM-machine, the CAD model is sliced into layers, brought into the best position and the necessary scale. Thirdly, the part is built in the AM machine with the layered concept. For that every machine has some actuating unit (laser beam source, jet nozzle, etc.), that actually builds the part by combining materials, which are typically sheets, wires, powders or liquids (Huang et al., 2013; Brajlih et al., 2011; Zhai et al., 2014). Lastly, the optional post-processing with additional parts removal, cleaning, polishing, coloring or coating can be performed afterwards, if necessary (Eyers and Dotchev, 2010).

The term additive manufacturing (AM) is often used interchangeably with other terms such as three-dimensional printing (3DP) and rapid prototyping (RP) (Fee, Nawada and Dimartino, 2014). However, the definitions of those concepts are inexact (Berman, 2012) and professionals do not agree on delimitation between them. To be able to analyze and compare AM-related innovations from their substitutes and assess the perceived attributes correctly, AM has to be demarcated from associated technical concepts. After the analysis of scholarly and managerial articles, three different logics for definitions have been found: (1) according to the technology, (2) according to the product and (3) according to the user group (Table 1).

#	Logic	Definition		
1	**According to the technology**	Additive Manufacturing	Formative Manufacturing	Subtractive Manufacturing
2	**According to the product**	Consumer Product (Additive/Rapid Manufacturing)	Prototype (Rapid Prototyping)	Tool (Rapid Tooling)
3	**According to the user group**	Professional / Industrial (Additive Manufacturing)	"Hobbyist" / Consumer (3D-printing)	

Table 1: Delimitation of Additive Manufacturing

According to the technology (1), there are three generic methodologies for manufacturing processes: subtractive, formative and additive. Subtractive processes, such as milling, remove material from a central part, whereas formative processes, such as injection molding, use a form or tool for production. Additive processes manufacture directly from a three-dimensional computer aided design (CAD) by joining materials layer upon layer (Hague, Mansour, Saleh and Harris, 2004; Goodridge et al., 2012; Ponche, Kerbrat, Mognol and Hascoet, 2014).

According to the product (2), AM is often used interchangeably with rapid prototyping (RP), rapid manufacturing (RM) and rapid tooling (RT). AM and RP are used synonymously, as AM was mostly used for the fabrication of prototypes. The manufacturing of end parts was labeled RM, AM, or when used for tooling, RT. Today, the term AM prevails as AM is common for the commercial production of consumer goods (Berman, 2012; Campbell et al., 2012; Goodridge et al., 2012; Onuh and Hon, 1998).

According to the user group (3), three-dimensional printing (3DP) is often used interchangeably with AM. However, when differentiated, AM stands for the professional use in an industrial setting and 3DP for the private use by households. This definition developed as 3DP is often associated with low-cost machines for consumers that differ considerably from industrial machines (Berman, 2012; Campbell et al., 2012; Hague and Reeves, 2013; The Royal Academy of Engineering, 2013).

Given the three logics, the study focuses on consumer products, produced in an industrial setting. Prototyping, tooling, as well as household applications (3DP) are therefore excluded from the study.

2.5.2 Perceived Attributes of Additive Manufacturing

In order to form propositions for AM's perceived attributes, it needs to be analyzed on its (1) relative advantage, (2) trialability, (3) observability, (4) complexity and (5) compatibility.

(1) Relative Advantage

Compared to conventional manufacturing (CM), AM has less technological constraints and can build parts with greater geometric complexity, without the need for tooling. Especially shapes that are impossible or difficult to create via other techniques can be produced and allow for full customization (Ponche et al., 2014; Eyers and Dotchev, 2010; Huang et al., 2013).

Additionally, AM is cost-effective for low quantities compared to CM. Given that no tooling is required, low volume production and customization of products becomes economically viable. With CM, high volumes have to be produced for the amortization costs for tooling (Goodridge et al., 2012; Berman, 2012; Eyers and Dotchev, 2010). However, even though fixed costs can be reduced, contrary to CM variable costs of AM are not decreasing with increased quantities (Berman, 2012). A further difference between AM and CM is its relatively higher speed in single batch production, as no tools have to be created and the set-up of machines is much faster. Yet, in mass production AM is considerably slower than CM due to process speeds (Goodridge et al., 2012; Ponche et al., 2014; Eyers and Dotchev, 2010; Huang et al., 2013).

Given the cost-effectiveness, speed advantages and possibilities for customization, the attribute relative advantage is present for AM in low volume production. Consequently, as relative advantage is positively related to an innovation's diffusion (Rogers, 2003), following proposition can be made:

⊕ P 1	AM's high relative advantage in low volume production is expected to have a positive effect on its diffusion.

(2) Trialability

AM has been used for single batch production in prototyping since decades and nowadays established manufacturers produce single products on demand (Berman, 2012; Hague and Reeves, 2013). Trialability focuses on the experimentation with the innovation, in this case the AM machine. However, with manufacturing technologies, it is the output, not the technology itself that is interesting for the adopter. For AM, it is not only easy to try out the machine, but also to produce single trials and assess whether the output of the manufacturing process is suitable for the own needs (Wohlers, 2014).

Therefore, trialability is one of AM's most inherent factors, as it can be easily experimented with. Given that trialability is positively related to the adoption of an innovation (Greenhalgh et al., 2004), the following proposition can be made:

⊕ P 2	AM's high trialability is expected to have a positive effect on its diffusion.

(3) Observability

The perceived outcomes of AM's adoption do not have to be sought in the machine, but in the finished products, as adopters are predominantly interested in what they can produce with AM. Here products can have increased functionality or be constructed in ways that have previously not been possible. However, it is also possible to produce products that are identical to traditionally manufactured products and therefore have no observable difference. Resulting from that, observability has to be seen nuanced, as AM can have clearly observable benefits, when previously non-producible products are manufactured. There are multiple examples, with shapes impossible to mill or cast, such as jet fuel nozzles or titanium-made bone implants. However, when products are just replicated for their relative advantage, but do not change in form such as dental crowns or hearing aids, AM is not visible to potential adopters (Hague and Reeves, 2013; Goodridge et al., 2012).

Therefore, AM has a high observability, when previously non-producible products are manufactured. Given that the attribute observability is positively related to the adoption of an innovation (Denis et al., 2002), the following proposition can be made:

⊕ P 3	AM's high observability for the production of otherwise impossible products is expected to have a positive effect on its diffusion.

(4) Complexity

Processes change when AM is used. Not only the manufacturing process changes, but also the development and design begins to rely heavily on CAD skills, scanning technologies and the optimization of digital models for AM. Compared to CM, post-processing is often needed with AM, as products rarely have the final surface or form after production. Additionally, materials behave differently when additively manufactured. This increases the complexity to choose the right materials for AM, and creates a demand to redesign and reengineer the application to the new material standards (Lados et al., 2014; Ponche et al., 2014; Zhai et al., 2014).

Therefore, the attribute of complexity is relatively high for AM. Given that complexity has a negative effect on the diffusion of an innovation (Tidd, 2010) the following proposition can be made:

⊖ P 4	AM's high complexity is expected to have a negative effect on its diffusion.

(5) Compatibility

AM changes the way that design and production economics have to be applied (Hague and Reeves, 2013; Huang et al., 2013). Therefore, experiences of potential adopters can be challenged in terms of work roles and power structures, as a change in work processes is accompanied by a change in responsibilities and relative task importance. New tasks that potential adopters are not used to and might not be able to fulfill are also necessary. Such changes increase uncertainty among potential adopters, as they do not know what the exact change in case of adoption for them will be (Barley, 1990; Compagni et al., 2015).

Consequently, the attribute of compatibility is relatively low for AM. Given that compatibility has a positive effect on the diffusion of an innovation the following proposition can be made:

⊕ P 5	AM's low compatibility is expected to have a negative effect on its diffusion.

2.5.3 The Medical Industry as Social System

Likewise the factors conditional to the medical industry have to be specified in order to analyze their effects on diffusion. Those encompass the previously introduced (1) opinion leaders and change agents, (2) innovation-decisions, (3) social structure and system norms and (4) communication channels.

(1) Opinion Leaders and Change Agents

The first and foremost adopters of innovations in the medical industry are physicians and other medical professionals that want to use an innovation. Physicians are constantly searching for better technologies in all medical device areas that are aligned with patients' needs as they are the core stakeholder for the control of performance and quality in healthcare (Ciurana, 2014). Additionally, research shows the importance of the user in the development of medical devices and the knowledge of medical professionals, thus greatly affects the innovation process. Physicians, nurses and technicians are the main users of medical technology and therefore its utility mainly depends on their perception of it (Hermelin, Dahlström and Smas, 2014).

Given this user-centricity in medical innovations, physicians can be identified as opinion leaders in the medical industry. Iyengar, Van den Bulte and Valente (2011) found in their study about the diffusion of new drugs among physicians, that physicians are affected by peers they deem as experienced and trustworthy. Here potential adopters were not only affected by peers' usage, but even more by usage volumes of adopters, as they ascribed those heavy users a larger experience base (Iyengar et al., 2011). Similar observations have been made by Barker (2004), who observed opinion leaders' influence in a HIV/AIDS prevention campaign to increase participation by 124% and Lomas et al. (1991), whose study showed that opinion leaders' influence decreased the rate of cesarean births. Supporting, Putzer and Park (2012) found that physicians are willing to adopt and promote technology innovations that benefit patient care. As stated before, AM has a significantly positive effect on the quality of care for patients (Bibb et al., 2006; Poukens et al., 2008; Sercombe et al., 2008). Therefore, the following proposition can be made:

⊕ P 6	Physicians as opinion leaders are expected to have a positive effect on the diffusion of innovations in the medical industry.

(2) Innovation-Decisions

When physicians agree to champion an innovation there are regulatory demands that are affecting its diffusion. Medical devices have to be beneficial for patients in short and long-term and have to adhere to safety standards (Ciurana, 2014). Strict quality controls are necessary to obtain product certification such as the CE-label (Conformité Européenne) in Europe and the FDA approval in the US (Ciurana, 2014; Grebel and Wilfer, 2010; Hermelin, et al., 2014). The governing bodies for those regulations can be found on regional, national and even transnational level as medical knowledge develops and spreads internationally. For instance, the WHO, the EU, and the OECD issue comparisons of national medical systems and give recommendations for technology assessments, such as the Health Technology

Assessment (HTA) (Blomgren, 2007). Even though regulations vary between countries, there are international forces for standardization. It is common practice in developed countries to evaluate technologies based on HTA, which is constructed after the principles of evidence-based medicine and scientific advice. Assessment studies (e.g. clinical trials) are performed and the performance of new technologies has to be proven through factual knowledge. HTA evaluates whether certified technologies are also cost-effective for the purchaser and gives recommendations for technology integration in health care standards (Atun, Gurol-Urganci and Sheridan, 2007). Clinical trials are at the center of all evaluation and make heavily tested technologies more likely to be certified and recommended, which affects less tested innovations adversely (Blomgren, 2007; Nedlund and Garpenby, 2014).

Given that regulatory bodies have to approve medical innovations, decision-making is a central factor for the diffusion of innovations. The highly regulated environment of the medical industry implies that authoritative innovation-decisions are at its core. These entail that the choice for rejection or adaption is made by few members of the system who hold power, status or technical expertise (Rogers, 2003), as in this case regulatory bodies. Similarly, McClellan and Kessler (1999) found that the diffusion of high technology heart treatments was strongly influenced by local regulations amongst others, which can be backed up by Hashimoto et al. (2006) in their study about coronary stents. Accordingly, Grebel and Wilfer (2010) found that needed certifications for hearth treatment technology had a negative effect on their diffusion. Therefore, the following proposition can be made:

⊖ P 7	Authoritative innovation-decisions are expected to have a negative effect on the diffusion of innovations in the medical industry.

(3) Social Structure and System Norms

To diffuse innovations in the medical industry, physicians are aware of the fact that they need assistance in understanding the technology that is at their disposal. Therefore, different stakeholders such as universities and medical device companies are involved in the adoption of innovations in the medical industry. There is a need for cooperation among them, given the need for feedback from medical professionals in the development of medical innovations (Anell, Glenngård and Merkur, 2012; Ciurana, 2014; Hermelin et al., 2014). Consequently, cooperation between physicians and engineers is necessary to create improved medical products that can be diffused (Ciurana, 2014). These diverse stakeholders are not interacting on a regular basis and have thus no shared network. In a strong network, members have frequent exchanges and many shared projects, whereas in weak networks members have few, if any, connections to each other. In general, it is harder to communicate innovations in weak networks, as members lack trust among each other and communication is less likely to reduce uncertainty (Farr and Ames, 2008).

Cooperation between multiple stakeholder groups is not only needed in the development of medical devices, but also for their diffusion. However, those stakeholders are highly dissimilar, as they work in different environments such as medical device companies, hospitals or universities and are not interacting with regular frequency (Farr and Ames, 2008). Studies show that evolved networks are superior in the mobilization of its members considering public health, whereby evolved means that many different stakeholders have a high frequency of exchanges (Goodman et al., 1998; Farr and Ames, 2008).

Dissimilarity among adopters and low frequency of exchanges are related negatively to the diffusion of innovations (Farr and Ames, 2008). Given this, the following proposition can be made:

⊖ P 8	Weak network structure is expected to have a negative effect on the diffusion of innovations in the medical industry.

(4) Communication Channels

There are two main channels that medical professionals use to get information about innovations, targeted media in the form of journal articles and interpersonal communication. Targeted media are used by researchers to publish clinical studies and have the goal to show peers the attributes of a new innovation (Brownson, Jacobs, Tabak, Hoehner and Stamatakis, 2013). Those publications are used similarly to mass media to generate awareness knowledge and inform peers about the innovation's existence. However, these publications are often neglected, as researchers' priority is the discovery of innovations and not its communication. Similarly, practitioners have the actual application in focus. A study by Brownson et al. (2013) found that researchers and practitioners likewise stated that they are not responsible for dissemination of results. More than two thirds of sampled researchers in the medical field spent less than 10% of their time on dissemination of results. This leads to low awareness knowledge about potential innovations among medical professionals.

Even though awareness knowledge is low, interpersonal communication is stronger related to the diffusion of an innovation in general (Rogers, 2003). Interpersonal communication is used extensively among medical professionals for the exchange of information (Coiera, 2006). Tang et al. (1996) found in a study among clinicians that on average 60% of physicians' clinic time was used for interpersonal communication. Given that the extensive use of interpersonal communication is positively linked to the diffusion of innovations (Tidd, 2010), following proposition can be made:

⊕ P 9	Use of interpersonal communication is expected to have a positive effect on the diffusion of innovations in the medical industry.

2.5.4 Summary of the Theoretical Framework

After the system-related factors for diffusion have been reexamined in the context of the medical industry, the factors expected effect can be specified to the context. The context of the study, framed by the propositions, is integrated in the theoretical framework, summarizing the systemic view (Figure 4).

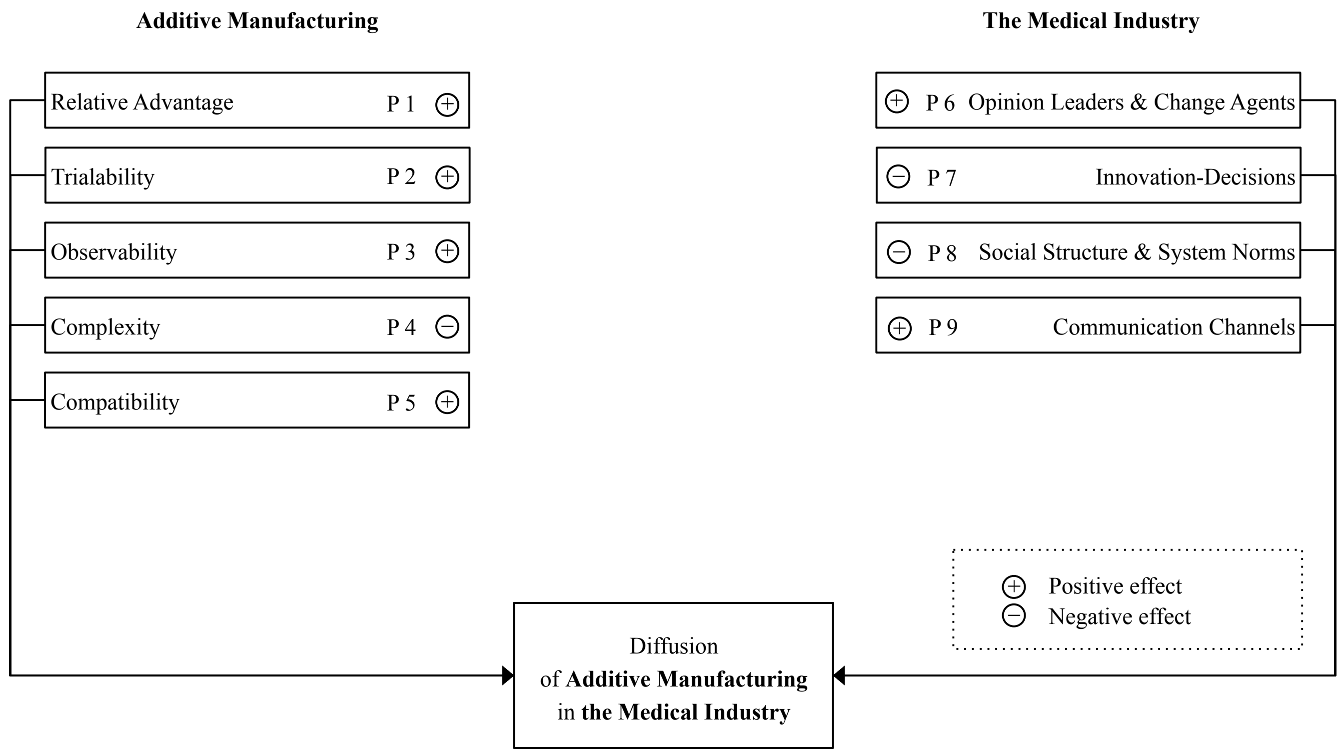

Figure 4: Theoretical Framework

The factors act as starting point for data collection, as well as analysis. The categories of the framework are tested against the empirical data and can be adapted when necessary. The following chapter illustrates the methodology of the study, which shows how the empirical data are analyzed with the framework.

3. Methodology

The chapter provides an overview of the research design (3.1) introduces data collection and documentation (3.2) and explains the data analysis (3.3). The section closes with a critical view on the study's reliability (3.4), validity (3.5) and its limitations (3.6).

3.1 Research Design and Methodological Fit

The aim of the study is to analyze the present factors for the diffusion of AM, as well as their effect on diffusion and expand on the current state of research. Therefore, the paper is based on an exploratory, qualitative research design with the help of semi-structured interviews. An exploratory research approach is well suited when there is little information about the research area (Stebbins, 2001), which is adequate for the diffusion of additive manufacturing in the medical industry. To research in such a nascent field, qualitative research is supported, as qualitative data are fitting for the analysis of insufficiently understood phenomena (Edmondson and McManus, 2007). Additionally, the use of qualitative interviews is a well-suited approach to get rich empirical data (Eisenhardt and Graebner, 2007). Propositions have been used to place limits on the study's scope and increase its feasibility. Here, propositions are based on literature and results from previous studies about AM or the medical industry and guide the data collection and discussion when integrated into the theoretical framework (Baxter and Jack, 2008).

The Swedish medical industry is used as the case object, as geographical proximity was important for the authors who are living in Sweden to get enough participants of the same social system in an appropriate time. A case study has the best methodological fit to the research goal, as they are well suited for exploratory, qualitative research (Yin, 2014). Moreover, case studies are appropriate to research a contemporary phenomenon more in-depth in within its actual context and when "how" questions are asked (Eisenhardt and Graebner, 2007; Yin, 2014). They are especially useful for the detailed analysis of phenomena, because of their generation of rich data (Eisenhardt and Graebner, 2007). However, it has to be differentiated between single and multiple case studies, as both have their advantages and disadvantages (Díaz Andrade, 2009; Yin, 2014). On the one hand, theories from multiple case studies are generalizable to a greater extent (Eisenhardt and Graebner, 2007), yet, it is also more difficult to find comparable case objects (Yin, 2014). On the other hand, single case studies allow for the creation of more complex theories, as the theory can be fitted to the details of a very particular case (Eisenhardt and Graebner 2007). Nevertheless, even though multiple case studies are generalizable to a greater extent, also single case studies can contribute to the understanding of a phenomenon (Siggelkow, 2007). Consequently, the Swedish medical industry was taken as single case. The Swedish medical industry allows for a profound analysis of the phenomenon due to its manageable size, while being large enough to ensure sufficient possibilities to gather data.

3.2 Data Collection and Documentation

30 interviews were conducted, which is a sufficient empirical foundation according to Bazeley (2013). Additionally, Guest, Bunce, and Johnson (2006), who analyzed saturation criteria for qualitative research, experienced that 90% of codes had been created in their experiment after the coding of 12 interviews. In the context of the relatively small size of Sweden's medical AM industry, snowball-sampling was used to evaluate whether the sample is sufficient. Thereby, sampling ends when key interviewees cannot point to other relevant interviewees that have not been contacted (Payne and Payne, 2004). As interviewed industry experts pointed outside of Sweden for further experts, the authors felt confident that the sample is sufficient. Additionally, multiple stakeholders from government, academia and industry have been interviewed to get the most coherent picture of the socials system and not only the opinion of on audience such as the innovation's owners (Rogers, 2003).

Data were gathered with semi-structured interviews, as they are appropriate to research the "what" and "how", by asking open questions for deep insights from the interviewees (Edmondson and McManus, 2007; Miles, Huberman and Saldana 2014; Saunders, Lewis, and Thornhill, 2009). The basis questionnaire for the interviews is divided into five parts (Appendix I) and rests on the theoretical framework. Interviews started with a short inquiry about the interviewee's background and the first time he or she had come into contact with AM in the medical industry. Subsequently, interviews followed a natural flow with the questionnaire as guideline, to make sure that all the five areas had been discussed. Depending on the interviewee's experience and occupation, questions varied and have been adapted to the interviewee's answers. The semi-structured nature of this approach made it possible to evaluate the gathered data throughout the interview and focus on research topics the interviewee seemed to be most knowledgeable in (Saunders et al., 2009; Yin, 2014).

Although an objective result is desired, it is acknowledged that subjectivity is inherent to the interpretation of qualitative data. Interviewee`s answers might be biased as it is possible that they have forgotten certain details or wish to alter or misrepresent what has actually happened (Lacity and Janson, 1994). Consequently, official industry and government reports, such as VINNOVA's[1] agenda for AM were acquired to clarify interviewees' statements during interviews. This usage of those documents was benefitting for the immediate triangulation of data from interviews (Miller, Cardinal and Glick, 1997; Voss, Tsikriktsis and Frohlich, 2002).

The 30 interviews were conducted via telephone (24) or face-to-face (6) between January 8th 2015 and March 25th 2015. The high ratio of telephone interviews is resulting from the geographical spread of the interviewees. The interviews lasted 15 to 100 minutes with an average of 50 minutes. Both authors tried to be present at each interview, to avoid a differing interpretation of the gathered data (Eisenhardt, 1989). In case this was not possible, interviewees were asked whether they would approve the interview's recording, to allow the absent author to evaluate the interview afterwards and compare the gained interpretation. The interviews where either held in English, Swedish or German, as Swedish is the native language of 29 of the interviewees and of one of the authors. The interview in German was

[1] VINNOVA is Sweden's governmental agency for innovation, affiliated to the Ministry of Enterprise, Energy and Communications, acts as national contact for EU R&D programs and is an expert for innovation policy (VINNOVA, 2015).

held, as the interviewee's and the interviewer's native language is German. As both of the authors were mostly present, 24 interviews have been conducted in English.

Culture becomes an aspect when the researchers have a different cultural background than the interviewees. Differences in the cultural background can create misconstructions, as researchers can misunderstand statements or miss subaudition (Fontana and Frey, 1994). This factor was mitigated as at least one author has the same cultural background as the interviewees. Moreover, the differing cultural background of the authors have led to valuable discussions about what had been said and what had been implied. To cope with semantic errors in translations, multiple techniques such as forward translations, back translations and bilingual tests have been evaluated. However, as only one of the authors is native in either Swedish or German, forward-only translations have been used for transcripts. This is most applicable when just one translator is available and no cross-cultural comparisons are planned (Maneesriwongul and Dixon, 2004).

Both authors have transcribed the interviews in English, whereupon notes have been discussed and integrated. To familiarize with the data, recordings, if available, were listened to afterwards (Bazeley, 2013). Additionally, interviews were evaluated within 48 hours to save the immediate impression, as well as re-evaluated after one week to ensure that perceptions of what had been said remained stable. Given that there is no one right way to transcribe interviews (Silverman, 2013), the continuous handling of the data seemed to be the most appropriate way of dealing with the qualitative information gathered. Additionally, ethical aspects in the construction and execution of the research design have been upheld. Specificity, objectivity and honesty have been kept in all communications to minimize the bias in the collection, analysis and interpretation of data (Bell and Waters, 2014; Gregory, 2003).

3.3 Data Analysis

Data collection and analysis partially overlap in the research with semi-structured interviews (Edmondson and McManus, 2007). To mitigate that fact, data collection was carried out as close to the conversation as possible (Bazeley, 2013), meaning that own interpretations have been left out of all transcripts and recorded data. The analysis was carried out based on coding and thematic analysis. This methodology is well suited for analysis of rich data and especially used in under-researched areas, with interviewees whose points of view are unknown (Braun and Clarke, 2006).

Coding and thematic analysis are often understood to be the same thing. The differentiating factor is that the development of themes depends on coded data (Bazeley, 2013). Consequently, even though thematic analysis is at times considered as a standalone method (Braun and Clarke, 2006), this paper is an accordance with Bazeley (2013) and Saldana (2013) and takes theme building as step in theory building from coding. To get the most out of the qualitative data, different reasoning approaches have been used. An inductive reasoning approach has been used during coding, making it data-driven and free from own subjective alterations due to the knowledge of the researched theory. Additionally, it was accurately coded what was said and not what might have been meant, which prevents semantic errors due to subjective changes in wording (Braun and Clarke, 2006). Statements can thus have multiple codes to show relationships when appropriate, or when the statement addressed several topics.

Both authors coded individually, evaluated differences afterwards and made adjustments in the final coding to minimize subjectivity (Miles, Huberman and Saldana, 2014). In the next step synonymous codes have been condensed to categories, showing relationships between data (Bazeley, 2013). Even though the categorization was aimed to be inductive, the author's previous knowledge of the theoretical framework made this intricate, thus adding a deductive filter over the data as well. This created a more realistic abductive reasoning approach and helped to continuously compare induction and deduction (Suddaby, 2006) (Figure 5).

Figure 5: Data Analysis, based on Saldana (2013)

Subsequently, categories have been classified deductively into themes, linking them to the theoretical framework, while examining them against the research question. The analysis is prioritizing the theoretical interest, generating a detailed analysis of the focused research aspect, while ascribing less importance to a more detailed overview of the overall data (Braun and Clarke, 2006). Themes were reevaluated on proximity to the raw data gathered, as well as to the fit with theoretical framework to avoid a verification bias that leans towards the author's preconceived ideas (Flyvbjerg, 2006). Figure six exemplifies the data analysis process, whereas a more detailed excerpt of the process is included in Appendix II.

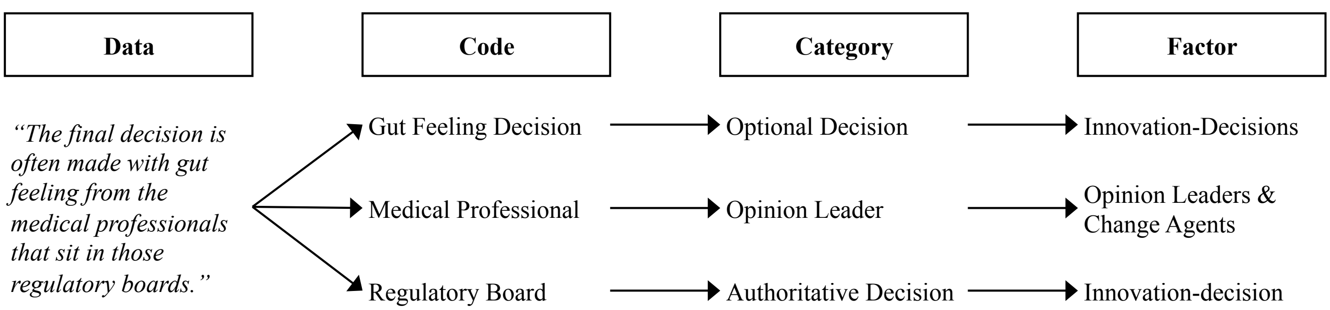

Figure 6: Example of the Data Analysis Process

3.4 Reliability

The concept of reliability describes the replicability of a study's findings for other researchers. Thus, minimizing individual biases in research and increasing objectivity of results (Yin, 2014). A study is not reliable and biased when the data could be interpreted differently by other researchers (Silverman, 2013). To minimize the threat of biased data interpretations and increase reliability, both researchers were present in most interviews. When this was not possible, the missing interviewer got a recording of the interview in order to compare perceptions of what had been said. When opinions about the data differed, the differing content was discussed and causes for the discrepancies sought. Additionally, coding was firstly done separately and then compared, to increase the reliability of the codes, categories and themes generated, such as theory suggests (Bazeley, 2013; Yin, 2014). Consequently, the fact that this paper has been written by two authors gives it an additional layer of reliability, which would not have been possible when writing alone. To secure documentation, transparency and replicability, the process steps have been documented with Microsoft Excel. Nevertheless, despite the measures taken to secure reliability, some subjectivity is not avoidable in qualitative research (Elliott and Timulak, 2005). Additionally, findings might lose reliability over time, which is inherent to the study as it analyzes factors at one point in time, which might change (Marshall and Rossman, 2010).

3.5 Validity

The concept of validity can be divided in internal as well as external validity and is especially relevant for exploratory case studies (Yin, 2014).

Internal validity refers to a study's closeness to reality in contrast to "few well-chosen examples" (Silverman, 2013, p. 276). To increase internal validity a copious sample of interviewees with various backgrounds are necessary (Eisenhardt and Graebner, 2007). However, as Payne and Payne (2004) highlight, the people that are picked inevitably play a role in the findings that are discovered. Consequently, in order not to be exposed to the subjective opinion of one interest group, interviewees from various positions inside and related to the medical industry have been chosen (Appendix III). This ensured a sampling that tries to mitigate biases and allows the research of a range of conditions (Payne and Payne, 2004; Voss, Tsikriktsis and Frohlich, 2002). Additionally, by coding and including statements of the interviews, not only the result of the presented empirics can be shown, but also the frequency in which the topics had been mentioned (Bazaley, 2013).

External validity considers the generalizability of a study (Yin, 2014). It can be argued that findings about the diffusion of AM in the Swedish medical industry might not be generalizable for other countries medical systems, other AM application areas, or for deeper insights into diffusion. However, the dimensions act as delimitation of the case study, which is important for its effectiveness (Yin, 2014). Furthermore, generalizability is aimed to be closer to the concept of transferability, which comprises the use of results from a study for a different research setting and is also called case-to-case transfer. Thereby, the researcher delivers exact descriptions, allowing other researchers to make assumptions about the application of the findings to other settings. Consequently, transferability is achieved by the researchers and their readers together, whereas readers transfer the researcher's results (Firestone, 1993; Lincoln and Guba, 1985; Polit and Tatano Beck, 2010). Given that, the case design can be applied to AM research in other countries' medical industries or used for the research of the diffusion of AM in other social systems. Moreover, is generalization not to be seen as absolute, as situational conditions always play a role in diffusion. Even measurement expert Lee Cronbach (1975, p. 125) agreed that: ''*When we give proper weight to local conditions, any generalization is a working hypothesis, not a conclusion*". Given that, the question of generalizability should be less of an absolute, but rather ask how much of the results can be generalized (Lincoln and Guba, 1985, Polit and Tatano Beck, 2010).

3.6 Limitations

The study involves data collected from a population at one specific point in time and can thus be considered a cross-sectional study (Payne and Payne, 2004). As Rogers points out (2003, p. 126), “by definition, an innovation diffuses in a process through time”. Accordingly, time is always a relevant factor when researching diffusion, as research participants are asked about their past history with the innovation. Based on that, the recall problem in diffusion research is a limitation to the study. Depending on the innovation’s importance to the interviewee, the length of time to recall and the individual differences (e.g. memory, education), the research participant’s memory can differ. Nevertheless, most of the diffusion research consists of correlational analyses of cross-sectional data gathered though surveys despite the existence of alternatives (Rogers, 2003). Field experiments, longitudinal panel studies, use of archival records and case studies of the innovation process with data from multiple respondents, can help to mitigate the problem (Rogers, 2003). The scope and the time frame of this paper do not allow for a field experiment or longitudinal studies and archives do not exist due to the nascent state of the industry. Consequently, the case study with multiple respondents has been chosen, to exploit the advantages of the relatively young age of the technology. Nevertheless, a recall bias cannot be completely omitted and limits the paper, as personal interviews ask to recall a longer period of time and states of mind over a couple of years (Rogers, 2003).

Additionally, the choice for a single case method against a multiple case method has been made. Although the single case study can go more in-depth, it neglects generalizability for the results (Yin, 2014). Especially as diffusion is a partially sociological process, comparable results from other countries would give the research more reliability. Going into such depth in several countries would not have been possible under given time constraints. Thus, while it would have been valuable to compare findings across cases, the trade-off would have been less detailed findings in each case. Consequently, a more in-depth analysis was chosen in contrary to a more generalizable one.

4. Empirical Results

The chapter introduces the study's interviewees (4.1), before the findings for the perceived attributes of AM are presented (4.2). Finally, factors pertaining to the medical industry are illustrated (4.3).

4.1 Overview of the Interviews

In order to show that the study incorporates knowledge from multiple stakeholders and professions involved in the adoption of AM in the Swedish medical industry, the participants of the study are introduced below (Table 2). The presented quotes are only identifiable by sector, not by name, to preserve a level of anonymity. For example, *Academic_Interviewee_5* refers to one of the researchers from Academia, but the number 5 has been randomly assigned.

Name	Sector	Occupation	Company / Institution / Organization
Andreas Fischer	Academia	Postdoctoral Researcher	Royal Institute of Technology
Annika Borgenstam	Academia	Professor	Royal Institute of Technology
Carin Andersson	Academia	Professor	Lund University
Henrik Gradin	Academia	Ph.D. Researcher	Royal Institute of Technology
Joakim Karlsson	Academia	Ph.D. Researcher	SP Technical Research Institute of
Jukka Lausmaa	Academia	Associate Professor	University of Gothenburg
Mats Falck	Academia	Director	Umeå University
Mats Falck*	Academia	Director	Umeå University
Mikael Bäckström	Academia	Ph.D. and Head of Department	Mid Sweden University
Olaf Diegel	Academia	Professor	Lund University
Peter Thomsen	Academia	Professor and Director	Gothenburg University
Stefan Peter	Academia	Ph.D. Researcher	University of Paderborn
Erik Borälv	Government agency	Programme Manager	Vinnova
Tero Stjernstoft	Government agency	Programme Manager	Vinnova
Annika Strondl	NGO	Research Leader and Manager	Swerea KIMAB
Evald Ottosson	NGO	Founder and Sales Manager	SVEAT and Protech
Malin Hollmark	NGO	Project Leader	Swedish Medtech
Marie Alpman	NGO	Science Reporter	Ny Teknik
Sten Farre	NGO	Senior Researcher	Swerea SWECAST
Anders Tufvesson	Private sector	CEO	GT Prototyper
Anders Westermark	Private sector	Associate Professor and Surgeon	Citytandvården and Medimar
Casper Rosén	Private sector	Sales and Service Technician	3D Center
Fredrik Finnberg	Private sector	Owner and Managing Director	Digital Mechanics
Jan Sätherlund	Private sector	Director	Xenter Yrkeshögskoleutbildning
Martin Wildheim	Private sector	Product Development Manager	Arcam
Martin Wildheim*	Private sector	Product Development Manager	Arcam
Ralf Carlström	Private sector	General Manager	Höganäs Digital Metal
Reza Kazemi	Private sector	R&D Manager	Dentware Scandinavia
Robert Andersson	Private sector	Owner	Solidmakarna
Stefan Thundal	Private sector	Product and Area Sales Manager	Arcam

* Follow-up interview

Table 2: Overview of the Interviews

4.2 Perceived Attributes of Additive Manufacturing in the Medical Industry

Interviewees have been asked about the perceived attributes of AM (Table 3) and answered with multiple medical device applications in mind. A generalization of those is possible, as all relate to the same layered manufacturing concept of AM. Therefore, different applications are further referred to as medical devices to omit confusion for the reader. To show the magnitude of how much a topic was discussed, it is presented according to the number of interviewees (I #) and according to the number of unique quotes documented (Q #).

Factor	Category	No. of Unique Interviewees (I #)	No. of Unique Quotes (Q #)	Codes	No. of Unique Interviewees (I #)	No. of Unique Quotes (Q #)
Perceived Attributes	Relative Advantage	24	135	Cost Speed Customization New materials …	16 16 14 7 …	35 31 31 15 …
	Trialability	7	12	Trials/Test/Try out	7	12
	Observability	25	11	Technical readiness/Visible development …	10 …	15 …
	Complexity	23	82	Design Post-processing Engineering / CAD skills …	10 10 7 …	14 13 11 …
	Compatibility	13	22	System- /Organization- /Role change Mental change …	8 7 …	8 11 …
	Adjacent Technologies	22	87	Technological type Material type …	19 12 …	45 29 …

Table 3: Excerpt of the Empirical Results for the Perceived Attributes of AM

4.2.1 Empirics: Relative Advantage

Interviewees clearly state that there is a relative advantage in the use of AM over CM in the medical industry. They mention diverse factors that are creating this relative advantage, such as lower cost for medical devices (I=16/Q=35), increased production speeds (I=16/Q=31) and the possibility to produce otherwise impossible products (I=7/Q=15), such as porous structures with titanium (for ingrowth in implants). Also customization has been named as an advantage as it allows physicians to create individual medical devices for each patient (I=14/Q=31).

> *“Doctors have a lot of benefits because they can customize their products. They can do 50 individual dental bridges in one batch.” (Academic_Interviewee_5)*
>
> *“There are more possibilities with AM than with traditional machining. […] AM is better with exotic materials and very complex geometries.*
> *(Private_sector_Interviewee_6)*

This relative advantage is positively connected to the diffusion of AM, as physicians seek better devices for their patients, with the above mentioned advantages. Therefore, the production of various devices, such as dental bridges or the acetabular cup, have switched from CM to AM based on relative advantage.

> *“Companies switch to AM because every device is customized to the patient so the potential gains in costs and time are significant.” (Academic_Interviewee_6)*

4.2.2 Empirics: Trialability

Interviewees state that it is relatively easy to try AM (I=7/Q=12). However, for physicians, trialability does not only mean that they can try the machine, it goes further, as they want to try the actual output, the medical device. With AM, they can create trials of the devices they want to produce.

> *“This is one of the big advantages of AM. With other production processes there are huge costs involved in setting up trials, and that means most cannot afford to do it.”*
> *(Academic_Interviewee_10)*

The ability to produce trials and try out the actual device reduces the uncertainty of adoption for the physician. CT, MRT and similar scans can be shown on the machines and give physicians a feeling for whether the device they want to have is possible. Consequently, it is easy to have a first assessment whether AM works without high costs. Interviewees also state that those tests are used in the medical industry and are often the first step for adoption.

> *"It allows them to very quickly test ideas to make sure they are 100% correct before proceeding to production. In terms of using AM for production […], companies that do small-volume-high-value products are beginning to use it for actual production." (Academic_Interviewee_10)*

4.2.3 Empirics: Observability

Interviewees state that the AM's adoption has low visibility in the medical industry among peers. Depending on the physician's involvement in the production of the device, it is even possible that the switch of the manufacturing technology passes the physician unnoticed (I=10/Q=15). This can especially be perceived in dentistry and for surgical tools, where technicians make the decision to switch. For other applications such as implants, adoption becomes visible to the user, as AM devices have increased functionality and have to be used differently. Therefore, it can be said that once the device changes its functionality, observability is present, yet only to the adopter that has used AM. When the device does not have increased functionality, there is no visible difference between AM and CM.

> *"I was once at a dinner conference, and sat with three other dentists. After telling them of the advantages of AM dental implants, they were all swayed and said that they would place an order for them to us. But then a dental technician chimed in, and informed them that they have already been using AM implants for a full year, apparently without realizing it." (Private_sector_Interviewee_9)*

The lack of observability, the non-seeing of an innovation's adoption, hinders AM's diffusion. As interviewees state, physicians simply do not know that AM has been used in many cases. This is mostly because physicians work according to specialization and use completely different medical devices whose functionality is not visibly linked. Even though physicians share their change in production method with others, it is not immediately visible to physicians from other specializations how AM can be of value to their respective practice.

> *"A lot of hospitals ask every day but they do not know what to ask for because they cannot specify it and then they ask the other doctors that have done it." (Academic_Interviewee_7)*

4.2.4 Empirics: Complexity

AM is perceived to be relatively complex by the interviewees. To learn how to design new forms of medical devices is perceived to be outside the skillset of medical professionals (I=10/Q=14). They perceive to need education that goes beyond the duties of a physician, such as engineering and CAD skills (I=7/Q=11). Also post-processing is seen as one of AM's additional complexities compared to CM. Post-processing creates the perception that the device leaves the AM machine unfinished and has to be completed with effort (I=10/Q=13).

> *"AM is the 180 degrees opposite of [CM]: A little manufacturing and a lot of engineering." (Private_sector_Interviewee_4)*

Complexity is seen as hindering for diffusion. Potential adopters are deterred because of the added complexity of engineering and design. Many do not want to adopt it, because they do not feel up to the task of using this novel technology.

> *"Sometimes what deters people is the post-processing (reheating, polishing, and taking away the support structures)." (Academic_Interviewee_7)*

4.2.5 Empirics: Compatibility

Interviewee's state that potential adopters do not perceive AM to be compatible with their existing experiences and needs. Even though they see the advantages, it is difficult to convince them that the increased benefits outweigh the changes in their current way of working (I=7/Q=11). Work roles can be changed quite severely as medical technicians have to switch from handcraft to AM, or physicians have to enter the domain of engineering. This creates uncertainty for them and makes them question whether they can manage to make the needed changes in their way of working (I=8/Q=8).

> *"The most common argument from potential customers against adopting AM tech is "why should we change?"" (Private_sector_Interviewee_7)*
>
> *"Today, the ones who do handle the printers are either self-taught, or the companies hire highly educated individuals who in earnest are overqualified for this task." (NGO_Interviewee_5)*

This incompatibility of AM with the existing status quo is perceived to hinder AM's diffusion. Medical professionals question why they should switch from their proven method, to something they do not understand. Consequently, there is a resistance to switch.

"The performance is good enough, but for many people it sounds like hocus pocus." (Private_sector_Interviewee_8)

"You are not prone to change [your methods] when you have good enough results. If you want to change something in the running system you get called stupid." (Academic_Interviewee_11)

4.2.6 Empirics: Adjacent Technologies

An additional finding that interviewee's mention is the usage of different sub-technologies of AM throughout the medical industry, as different medical applications demand different materials and processes. However, the core innovation of AM, the layered manufacturing concept and its process, remain the same. Often adopters want to fit the innovation to their unique needs and situation. In the medical industry it is perceived that many different sub-technologies are employed and the innovation thereby changed (I=19/Q=45). This leads to the usage of multiple technologies for different materials (I=12/Q=29).

"EOS and Arcam and Höganäs all have their own niche and business models. There is no dominant design. Arcam with its EBM is faster, but not as accurate as SLS." (Academic_Interviewee_5)

The emergence of those different technology types is often seen as reason that AM has not been used, because potential adopters fear that they might use the wrong process and consequently cannot create the best product. Additionally, the existence of those different processes creates the perception that the technology is not mature and should not be used for sensible products such as medical devices. This hinders diffusion of AM in the medical industry, as physicians want to wait till there are clearer facts about a best technology.

"There is misunderstanding, because people have read something in the morning paper. You just download a file and then you send it to the printer and then you have your finished product. That's not it." (Academic_Interviewee_5)

4.3 Perceived Factors of the Medical Industry Regarding Additive Manufacturing

Interviewees have been asked about the Swedish medical industry's perceived factors affecting the diffusion of AM (Table 4).

Factor	Category	No. of Unique Interviewees (I #)	No. of Unique Quotes (Q #)	Codes	No. of Unique Interviewees (I #)	No. of Unique Quotes (Q #)
Opinion Leaders and Change Agents	Opinion Leaders	27	149	Universities/Research centers Vinnova/Governmental agencies Doctors …	19 16 11 …	81 44 20 …
	Change Agents	22	111	AM Companies/Vendors/Sellers Investors/Funding/Grants Arcam AB/Höganäs SVEAT …	22 17 12 3 …	42 59 23 3 …
Innovation-Decisions	Optional Decision	11	28	One-time applications Physician's/Dentist's decision Manufacturer's decision …	10 9 6 …	19 18 8 …
	Authoritative Decision	25	147	Commercialized products available Regulatory approval/Certification Procurement process …	22 10 5 …	110 22 5 …
Social Structure and System Norms	Social Structure	23	103	Int'l Differences/Comparisons Public-Private Partnerships Small community …	23 9 6 …	88 16 12 …
	System Norms	25	83	Conservatism/Skepticism/Safety-oriented Relative time …	22 5 …	61 7 …
Communication Channels	Mass Media Communication	11	18	Mass Media /Media Internet	8 5	14 5
	Targeted Media Communication	7	14	Industry magazines Journals / Clinical documents	5 3	6 8
	Interpersonal Communication	11	19	Conferences/Exhibitions/Fairs …	10 …	18 …

Table 4: Excerpt of the Empirical Results for the Medical Industry's Factors for Diffusion

4.3.1 Empirics: Opinion Leaders and Change Agents

The financing of AM is mentioned as a major topic of engagement for opinion leaders and change agents alike. The government, with its innovation agency Vinnova (I=16/Q=44) is perceived as an early opinion leader since the beginning of AM in Sweden, providing grants and encouraging researchers to use AM. However, it is claimed that Vinnova stopped funding AM-related grant applications in the early 2000s. Here a shift in opinion leadership and a de-prioritization of AM against other technologies has been perceived. Nevertheless, Vinnova clarifies to be restricted by government practices and not completely free to choose its investments. Change agents are mentioned in the form of investors (I=17/Q=59) and are perceived as a critical factor for the diffusion of AM in the Swedish medical industry. Lack of investors and funding is a perceived barrier for AM. Researchers and practitioners claim not to get the necessary funding to pay upfront costs for machines and materials for AM. Here, AM machine vendors are mentioned as change agents that are trying to promote AM and change the funding situation with cost-reductions for their products (I=22/Q=42). Especially the Swedish firms Arcam AB and Höganäs are mentioned on that account (#12). Additionally, the industry organization SVEAT[2] is mentioned as facilitator in this process, even though it was founded as recently as 2014 (I=3/Q=3).

"Sweden was at the forefront of the development of AM in terms of R&D up until 2003-2004. Back then there was a lot of research on several institutions. But then the funding from Vinnova ended. They deemed it not a prioritized area anymore." (NGO_Interviewee_5)

"We [Vinnova] cannot advance an area just because it exists. We must always work with competitive tendering projects based on resource availability." (Government_Interviewee_2)

"[Universities] get highly discounted systems up to 90%. They seem to believe that they should get anything for free. But AM machines cannot be given away for free and also maintenance has to be prepared. […] It is an excuse of the universities that they have limited funds." (NGO_Interviewee_2)

The actual adopters of AM, the researchers and practitioners, are frequently mentioned as well. Here the most apparent are universities and research centers functioning as leading institutions (I=19/Q=81). The actual usage of AM is seen as necessary to be perceived as credible and as basis to convince medical professionals of the benefits of AM. Nevertheless, it is also mentioned that universities in Sweden are not cooperating enough, neither on an interdepartmental level, nor on a national level. According to the interviewees, there is presently no national agenda for AM. Another opinion leader group frequently mentioned as adopters are physicians (I=11/Q=20). They are the ones that promote

[2] SVEAT is a Swedish trade organization with the objective to promote AM through lobbying in order to increase Sweden's competitiveness. SVEAT is comprised of Sweden's leading suppliers of AM technology (SVEAT, 2014).

innovations among their peers and act as references for new technologies. However, it is stated that physicians are not actively promoting AM because they see risks in its usage and feel inadequately informed about its benefits.

> *“Mittunversitetet is one of the few that have purchased some machines. They initiated a lot of research in the medical area, exploring metal implants from a mechanical and biological point of view. However, it is very hard to establish relationships between the different practices.” (Academic_Interviewee_11)*
>
> *“Some people invest their entire life and career into something. They therefore don’t like the person who comes along and claims that something else is new and better. You need really good scientific evidence to go along with AM. Merely hypothetical benefits can always be argued against.” (Academic_Interviewee_11)*

There are two major topics among change agents and opinion leaders directly related to the diffusion of AM, the financing situation and the recommendations of medical professionals. The lack of funding is often perceived as the biggest barrier for the diffusion of AM as medical researchers and practitioners cannot find and assess new possible applications. Due to this inexperience with AM, physicians are not promoting a technology they do not feel to have the adequate knowledge about, which in turn again decelerates diffusion.

> *“For biologically or medically interested researchers it is much harder as they would not get the funding or grant to a machine that is very expensive. A biologist has normally just microscopes and much smaller equipment. The grants are much smaller.” (Academic_Interviewee_11)*
>
> *“Very difficult to make doctors buy [AM], because they do not understand it.” (NGO_Interviewee_2)*

4.3.2 Empirics: Innovation-Decisions

The innovation-decision process cannot simply divided be into optional, authoritative and collective decisions, because innovation-decisions interact and create different pathways for innovation activities. The physician’s/medical technician’s optional decision for the use of AM represents the starting point (Figure 7). The following decision path in the medical system is exemplified from a physician’s/medical technician’s perspective and is based on the empirics.

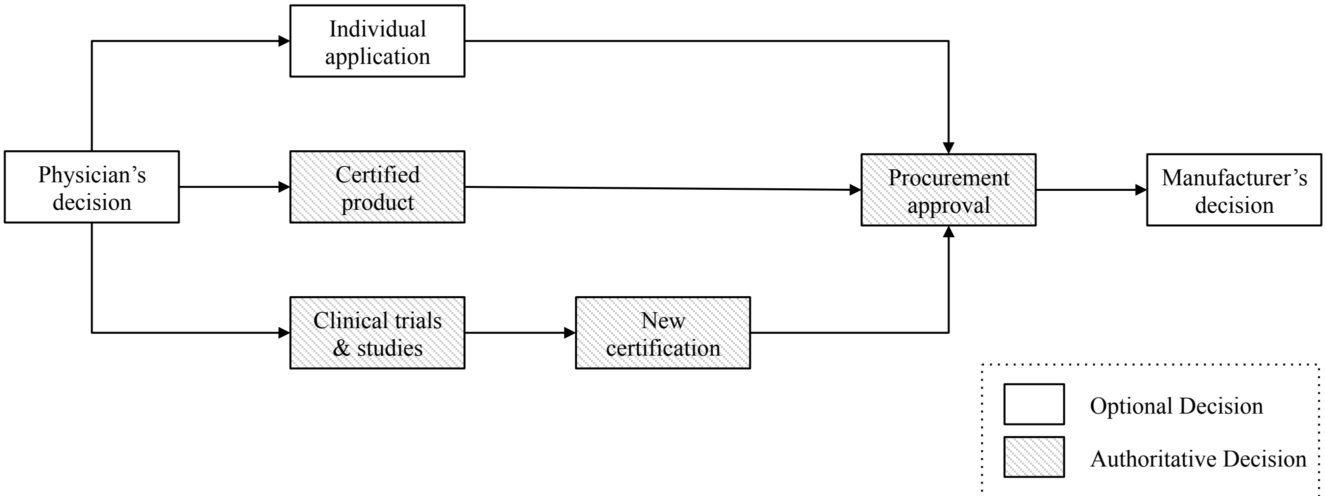

Figure 7: The Main Decision Paths for AM-Adoption in the Swedish Medical Industry

The physician's/medical technician's optional innovation-decision whether to use or neglect AM is mentioned as major decision point for the adoption of AM medical devices (I=9/Q=18). The physician or technician decides whether he or she wants to use AM or not. A physician decides, when he or she has to use a different treatment technique due to the changed functionality of the device (such as in implant surgery). A technician or physician decides when the treatment technique does not change, as devices are physically the same after the change in manufacturing technique. In case of adoption, there are three different possibilities to adopt AM: using an already certified product, trying to certify a product or providing the device as an individual application. When asked about the patient's individual decision-making power, it becomes clear that the patient does not make decisions based on different available techniques and is not even included in the process.

"It's always the operating doctor that decides what is being done and how [...]." (Academic_Interviewee_9)

"The patient does not know what he is getting. He cannot ask." (Academic_Interviewee_12)

In case the physician decides to use a certified product, he or she can only choose from some devices such as dental implants or acetabular cups (part of a hip replacement), whose processes and materials are certified (I=22/Q=110). Here authoritative innovation-decisions dominate the medical industry. When authorities have certified the product, no further efforts have to be taken to use those. At the same time, when the physician decides to use AM for a single application and accepts to bear full responsibility for the outcome of the treatment, no formal approval is needed (I=10/Q=19).

"The materials are already certified and then the production method has to be certified and then you do not need additional certification. You do not test every single device." (Academic_Interviewee_12)

"For the case of CE-marking, etc., it's actually one-off for the patient-specific implants. [...] In this situation, we don't need to have any formal approval of exactly that one plate. Because in this case, it is up to the operating physician to take the responsibility." (Academic_Interviewee_9).

However, for the certification of new applications, clinical trials and regulatory hurdles have to be taken, which is a lengthy process that can take years (I=10/Q=22). Clinical trials and evaluations are necessary, as regulatory bodies evaluate new technologies based on evidence. In any case, whether the physician uses a certified application, tries to certify a new one or uses AM as one-time treatment, the procurement process has to be taken into account (I=5/Q=5). The county council, the financier of the treatment, is involved along with expert committees in hospitals, to decide whether the application is necessary. After approval, manufacturers are not seen as an inhibiting factor in the diffusion of AM, as there are various players on the market that already produce medical devices on demand also in single batches (I=6/Q=8).

"For the person ordering the hardware, costs are very important. SLL [Stockholm's County Council] will pay for it." (Academic_Interviewee_6)

"It is no problem to get a customized implant. [...] You can get everything. Many colleagues contact me after they found a paper I have written or something on a website. It's just a few clicks away." (Private_sector_Interviewee_2)

Given the interviewees description it can be seen that even after the individual decision to adopt AM, regulatory hurdles have a negative effect on the diffusion of AM. Physicians often opt for the individual application and take the responsibility to circumvent regulations. However, this has the effect that the next physician who wants to do the exact same application has to face the same decision again. He/she either has to go through the long certification process, or choose to do it as individual application him-/herself.

"The need of approval of material components (for toxicity, etc.) by FDA, CE, etc. before they can be sold to consumers is the main difficulty/hindrance for quick commercialization in the medical industry for AM products."
(Academic_Interviewee_4)

The third kind of innovation decision, the collective innovation decision (consensus decision caused by the participation of each individual in the social system) (Rogers, 2003) has not been mentioned by the interviewees.

4.3.3 Empirics: Social Structure and System Norms

Networks are very apparent to the interviewees and most of them mention regional structures that separate Sweden from other countries (I=23/Q=88). AM is perceived to diffuse differently in countries, not only because of different regulatory systems, but also because of different research environments, funding situations and other national prerequisites. Sweden is perceived to be a small community, where everyone knows each other in the field of AM (I=9/Q=16). Here, networks of public-private partnerships (PPP) are mentioned as important for the advancement of AM, but not sufficiently realized (I=6/Q=12). PPPs are perceived to generate a mutual benefit for participating companies, researchers and governmental stakeholders. As a result researchers can get access to machines, whereas AM companies can improve processes and applications.

"At their university (a friend's university in Germany) they had 25 PhDs in AM and here they have 5 graduate doctors in AM in whole Sweden." (NGO_Interviewee_2)

"Research and academia is one of the most important stakeholders for the spread but they need help from the government. It's very interlinked. Universities work together with companies nowadays." (Private_sector_Interviewee_8)

"No cooperation between medical and technical departments in the university." (Academic_Interviewee_7)

The system is perceived to be accompanied by strong system norms (I=25/Q=83). Most of the interviewees mention safety orientation, conservatism or skepticism as most prevalent norms in the medical industry (I=22/Q=61). Physicians are perceived to value the patient's safety the highest and dismiss seemingly unsafe and risky innovations. This also manifests in the fact that some of the interviewees (I=5/Q=7) do now view that AM's diffusion is hindered, even though they know that the technological possibilities in Sweden are not fully exploited and that Sweden is lagging behind other countries.

Interviewees clearly see a link between the value orientation and diffusion. It is stated that the diffusion of AM is hindered due to this conservatism. Additionally, the scattered adoption is perceived to be the result of a lack in professional cooperation between the different stakeholders.

"I tend to believe that the medical industry is very conservative, so that's one of the main reasons why AM hasn't been deployed more than it already has." (Private_sector_Interviewee_4)

"AM is adopted on a case to case basis. There is no real expert society that is driving sales. In the earlier days, one third of the customers were universities and research centers (education), one third medical professionals and one third the airline industry." (Private_sector_Interviewee_6)

4.3.4 Empirics: Communication Channels

The Internet is seen as most-used mass media channel, used for sharing information about AM (I=5/Q=5). However, all mass media channels are seen as rather ineffective and more as a driver for public opinion than for the creation of knowledge (I=11/Q=18). Targeted media have particularly been mentioned by researchers (I=7/Q=14). For physicians, scientific publications and clinical trial documentation was seen as important to attain information (I=5/Q=6), whereas technical scholars referred to industry magazines (I=3/Q=8). Interpersonal communication has been mentioned as the most important channel in the form of industry conferences (I=10/Q=18). These conferences are seen as the prime spot for interested physicians, engineers and AM companies to convene and exchange information. They are seen as essential in getting to know the product and the people.

> *"Emerging scientific journals for AM. That is very interesting and tells you that it is taking off in the medical area." (Academic_Interviewee_11).*
>
> *"Certainly the Internet is very important but for the final decision the face to face meeting is more important." (Private_sector_Interviewee_2)*

Consequently, mass media coverage is not perceived as linked to the adoption of AM. It is rather seen as a first station to get information about what is possible. Likewise targeted media such as scientific publications are described as a way to gather information and not as an actual decisive factor for using AM. However, conferences have been mentioned as first stage in the adoption of AM. Even though the actual transaction is not made at the conference itself, the decision to try it is often made when the medical professionals and AM producers meet and interact with the actual products.

> *"Fairs are important because there lab owners and dentists and AM producers can meet and they can interact and make the physicians try, change and influence them." (Academic_Interviewee_5)*

5. Analysis

The chapter starts with the analysis of the perceived attributes of AM in the medical industry (5.1), before the findings of the system factors of the medical industry are analyzed (5.2). Here findings are tested against previously made propositions. Thereafter, the propositions and additionally found effects are summarized (5.3), to analyze additionally found interrelations and present the final result (5.4).

5.1 Perceived Attributes' Effect on Diffusion

The following chapter encompasses the analysis of the empirical findings about the perceived attributes of AM in the Swedish medical industry.

5.1.1 Analysis: Relative Advantage

Interviewees agree that AM has a relative advantage in the medical industry due to reduced costs, higher production speeds and possibility for customization, amongst others. Those are however just obtainable in the production of relatively low quantities. Given that high volumes are not needed in customized medical applications, as every device is unique, AM can clearly use its relative advantage against CM. Cronskär, Bäckström and Rännar, (2013) likewise discovered that customized hip stems were 35% cheaper when manufactured with AM, instead of CM, and the cost could further decrease to 50% by utilizing the total volume of the machine. Those advantages have also been discovered for multiple other medical devices such as dental products and hearing aids (Atzeni, Iuliano, Minetola and Salmi, 2012; Tuomi et al., 2014). Thus, the relative advantage presented in the interviews has also been confirmed in literature.

The link between the relative advantage and an increased diffusion of AM is also confirmed by the interviewee sample. Multiple respondents mention that several applications such as dental crowns, braces and some implants have already been adopted with AM, due to their increased performance, which can be confirmed by Wohlers (2014). Consequently, AM's relative advantage in low volume production has a positive effect on its diffusion in the Swedish medical industry.

⊕ P 1	AM's high relative advantage in low volume production is expected to have a positive effect on its diffusion.	Supported

5.1.2 Analysis: Trialability

AM is inherently linked to trialability, as it is a main technology for the production of prototypes in various industries such as automotive, aerospace and medical since decades (Hague et al., 2004; Onuh and Hon, 1998; Mellor et al., 2014). As potential adopters can not only try out the machine, but also try out what they are really interested in, the potentially produced good, trialability becomes even more valid for AM. Interviewees state that the possibility to perform iterative tests for customized medical devices is a clear advantage, as potential adopters can improve the original design in various iterations.

AM’s trialability becomes even more apparent when compared to CM, where new tools are required for each test (Berman, 2012; Campbell et al., 2012).

Trials help to reduce uncertainty about the innovation and the lower the potential adopter’s uncertainty, the higher the possibility of adoption (Rogers, 2003). Likewise, interviewees state that trials with AM made it feasible for them to easily test the product, which led them to switch the manufacturing method to AM. Consequently, the high trialability of AM has a positive effect on its diffusion in the Swedish medical industry.

⊕ P 2	AM’s high trialability is expected to have a positive effect on its diffusion.	Supported

5.1.3 Analysis: Observability

The empirical findings show that diffusion of AM can progress unnoticed by the adopters that handle the innovation on a daily account. In dentistry, the dental laboratory acts as intermediary between the dentist (the purchaser) and the AM service bureau (the manufacturer). According to the interviewees dental laboratories commonly order dental bridges produced with AM instead of CM, unknown by many dentists. To AM to be observable, the results of AM’s adoption have to be visible to other members of the medical industry. However, when the functionality or the shape of a device is not changed, there is no difference visible for adopters. Consequently, the observability of AM depends on the device that is produced.

Counterintuitively to the predicted proposition, even the products that would have been impossible to produce with CM, such as the titanium acetabular cup (Wohlers, 2014), have low observability. This is due to the fact that different medical departments need completely different medical devices that cannot be linked by functionality immediately. Even when physicians observe others to change their production method, it is not immediately visible to physicians from other specializations how AM can be of value to their respective practice. Similarly, researchers see the need for documentation and classification of medical AM devices, as this does not exist yet, which leads to physicians’ ignorance of the possibilities (Tuomi et al., 2014).

Therefore, observability is rather low for AM in the medical industry across applications. Consequently, the existence of high observability of AM for otherwise impossible products is unsupported for AM in the Swedish medical industry.

⊕ P 3	AM’s high observability for the production of otherwise impossible products is expected to have a positive effect on its diffusion.	Refuted

5.1.4 Analysis: Complexity

AM is perceived as a complex innovation with diverse requirements such as engineering skills, design skills and post-processing requirements. The production of customized products requires a rethinking of conventional products, which in return demands a mixture of design and engineering skills. Equally, Hague and Reeves (2013) and Mellor et al. (2014) state that design is indeed a barrier for AM's diffusion, as design does not have to follow CM anymore and rather has to be adapted to physical restrictions, than to technical ones.

However, there are complexities which are falsely perceived to be more severe than they actually are. Post-processing requirements are viewed as limitation to the diffusion of AM by interviewees. Those are however neither new, nor particularly complex tasks, as post-processing entails the removal of excess material and surface treatments like polishing. These tasks have been standard operating procedures in CM for years (Eyers and Dotchev, 2010).

Nevertheless, it is the perception of complexity that affects diffusion and not the actual level of complexity (Rogers, 2003). In the case for AM in the Swedish medical industry, high complexity of AM is perceived. Given that high complexity has a negative effect on diffusion, it can be supported that AM's high complexity has a negative effect on diffusion in the Swedish medical industry.

⊖ P 4	AM's high complexity is expected to have a negative effect on its diffusion.	Supported

5.1.5 Analysis: Compatibility

The fit of an innovation to existing values, experiences and needs is a significant attribute for an innovation's diffusion. The less people need to change their way of working, the less likely the innovation is disregarded (Denis et al., 2002). Interviewees state that changing to AM from CM is perceived to include changes in how physicians and medical technicians work. New stakeholders such as AM service bureaus are perceived to change working processes. Considering the high level of manual labor in treatments, with physicians choosing devices based on experience and perceived best fit, the proven way of working gets disrupted. Experience is perceived to be disregarded and loses value when devices are simply produced directly from a medical scan instead of physicians' best judgment. This change in the way of working can also be confirmed by Wagner, Daintry, Hague, Tuck and Ong, 2008) who assessed the effects of AM adoption on needed employee skills in the prosthetics profession.

This rejection based on a mismatch with existing experiences hinders the diffusion of AM. Consequently, the proposition that AM's low compatibility hinders the diffusion of AM in the medical industry can be supported.

⊕ P 5	AM's low compatibility is expected to have a negative effect on its diffusion.	Supported

5.1.6 Analysis: Adjacent Technologies

This modification of an innovation is called re-invention and describes the extent to which an innovation is "modified by a user in the process of adoption and implementation" (Rogers, 2003, p. 180). When adopters can adapt an innovation to their own needs it is more easily adopted (Greenhalgh et al., 2004). Because of this, different sub-technologies are not neglected in this study, but instead analyzed under the concept of re-invention, satisfying the need for a clearly limited research area, without neglecting the complexity of AM. Therefore, re-invention has been added as an attribute affecting the perception of an innovation and consequently also its diffusion.

When technologies are re-invented they are more likely to be adopted than rejected. However, re-invention also produces more uncertainty since it alters work procedures and disrupts the existing system, resulting in confusion and insecurity (Papa and Papa, 1992). According to the interviewees, there are multiple technologies (e.g. SLS, EBM, …) suitable for different applications. There is confirmation that diffusion is facilitated when medical technology is adapted to the wishes of medical professionals. However, this is related to the produced device and increased possibilities for treatments and not for the manufacturing technology that devices are produced with. Hashimoto et al., (2006) found accordingly that coronary stents had to be adapted to the smaller physique of Japanese people, for them to be more widely adopted.

However, what effects the perception of medical professionals about AM, is the magnitude of AM technologies, each with its own advantages and disadvantages. Interviewee's state that there is no best technology yet, no dominant design, so they do not know which technology is feasible for their potential applications. The relatively high occurrence of re-invention, does not lead to an improved adoption rate, but rather leads to confusion and insecurity on what to choose, similarly to be found by Papa and Papa (1992). Therefore, the re-invention of AM in the medical industry increases uncertainty and has a negative effect on its diffusion.

⊖ **P X**	High levels of re-invention for AM have a negative effect on its diffusion in the medical industry.	

5.2 The Medical Industry's Effect on Diffusion

The following chapter encompasses the analysis of the empirical findings about the system factors of the Swedish medical industry in relation to AM.

5.2.1 Analysis: Opinion Leaders and Change Agents

Interviewees and scholars, both, mention the physician and other medical professionals as the first and foremost decision maker for the adoption of AM (Ciurana, 2014). Given the nascent state of AM in the medical industry (Wohlers, 2014), AM is mostly adopted by medical professionals who are also researchers. The activities of those medical researchers to promote AM among their peers have been described as almost non-existent. Few people try to promote AM and if they do, it is only within their respective specialization. According to the interviewees, physicians that are not researchers do not understand AM yet and do not feel able to use it for medical devices. Even though scholars show that AM has high potential for medical devices (Cronskär et al., 2013; Wohlers, 2014), doctors still feel uncertain about how to use AM. Physicians either do not know about AM or are misinformed about risks and benefits according to the interviewees. Given that opinion leadership is accumulated and sustained through technical competence (Rogers, 2003) and by usage volumes as adopters (Iyengar et al., 2011), physicians in the Swedish medical industry are not able to fulfill this role due to their lack of experience. Most physicians are simply not seen as experienced enough to act as trustworthy role models that can decrease the uncertainty in the adoption of AM. Opinion leadership of physicians is especially important in the medical industry, as medical professionals are the core group for the control of performance and quality in healthcare (Hermelin et al., 2014). Thereby, multiple studies show the positive effect of physicians as opinion leaders (Iyengar et al., 2011; Lomas et al., 1991).

It is not that physicians are not generally opinion leaders in the medical industry, but rather that they do not have opinion leadership for AM. Consequently, physicians do not have a positive effect on AM's diffusion as opinion leaders.

⊕ P 6	Physicians as opinion leaders are expected to have a positive effect on the diffusion of innovations in the medical industry.	Refuted

Additionally, another finding involves of opinion leaders and change agents financing activities. Interviewees perceive that the government has deprioritized AM and given up its funding for AM in the Swedish medical industry. Especially opinion leader VINNOVA is perceived to have stopped efforts to promote AM and switched funding to other areas. This can be verified by documents from VINNOVA, which prove a significant decrease of investments from 5 MSEK in 2001 to <1 MSEK in 2008, whereby only two companies (Arcam AB and fcubic) have been financed at all from 2005 on (Åström et al., 2010). Given that VINNOVA previously financed AM and encouraged researchers and practitioners alike to explore AM, interviewees viewed defunding as a change in opinion leadership.

Interviewees report that there is a link between governmental funding and the diffusion of AM. Similarly, VINNOVA claims that the funding for Arcam AB, and especially for two projects regarding the development of titanium for AM medical implants, helped Arcam AB to be among the market leaders for this type of implants today (Åström et al., 2010). Companies agree that governmental assistance is not only necessary in the development, but also in the dissemination of new technology and that funding is an important part of that (Åström et al., 2010). Equally, Chung (2002), as well as Lee and Park (2006) found that governmental funding is essential for diffusion and the creation of a national innovation system.

This decrease in governmental funding clearly affected the diffusion of AM in the Swedish medical industry negatively, as financing in general is seen as a mayor problem. Medical researchers are not used to the heavy investment in machinery and materials. However, this lack of governmental funding has led to the emergence of other structural changes such as increased industry-university partnerships. The funding situation of research on innovations affects the building of those partnerships. According to a study of Sellenthin (2011), researchers in Sweden and Germany that experience a decrease in their base funding for applied research are more likely to enter industry-university cooperation. Similarly, interviewees report that AM vendors act as promotors and financiers for research in absence of governmental support. Change agents, such as Arcam AB, have a critical impact on AM research in Sweden, which is in line with reported positive effects of industry-university cooperation for diffusion of innovations (Lee and Park, 2006). Therefore, the decreased levels of governmental funding are expected to increase the emergence of industry-university cooperation.

⊕/⊖ **P XI**	Decrease in governmental funding for AM leads to an increase in industry-university cooperation in the medical industry.

5.2.2 Analysis: Innovation-Decisions

The medical professionals initial decision point to use AM is seen as the starting point for innovation-decisions in the Swedish medical industry. Hereby, it is not up the patient to decide whether the used device should be additively manufactured. Similarly Grebel and Wilfer (2010) state that the patient does not have much choice in the method in which he or she is treated, as there is a great information assymetry between patient and physican. Therefore, patients rely on the physicians to choose the best available treatment. This makes medical professionals' importance for diffusion apparent. Without their willingness to adopt there would be no diffusion. Consequently, they have to be conviced to adopt first, before they seek certification from regulatory bodies.

Authoritative decisions are mentioned as important gatekeepers on multiple levels in the Swedish medical industry. Certification regualtions as well as procurement policies are thereby seen as hindrances to AM's diffusion. Interviewees state that certification of devices is a lengthy process that is often circumvented by physicians with the use of single applications that do not need to be fully certified. This makes it visible that physicians try to circumvent the regulatory environment, even though they have to shoulder increased responsibility. Initially this sounds like the diffusion of AM is facilitated for single applications. However, a side effect of this is that less physicians opt for certification of devices and device classes. As a result, less clinical evidence which can be disseminated among physicians is created. Even though there are national quality registers that contain anonymized data about a physician's diagnoses, treatments and patient outcomes, healthcare facilities in Sweden report voluntarily, which cannot guarantee re-usable data (Blomgren, 2007). The circumvention of regulations leads, despite singular adoption, to little transferrable results. Given this, the high regulatory hurdles in the Swedish medical industry have two effects regarding the diffusion of AM in the medcial industry.

Firstly, it can be supported that authoritative innovation-decisions have a negative effect on the diffusion of AM in the medical industry, as physicians feel the process to be restrictive and hindering.

⊖ P 7	Authoritative innovation-decisions are expected to have a negative effect on the diffusion of innovations in the medical industry.	Supported

Secondly, the deterring effect of regulatory demands in form of certifications has a negative effect on the generation of clinical evidence that can be used to diffuse the technology. Physicians do not have to aim for certification but can make the individual decision whether to adopt or not. When physicians opt for individual applications, generated clinical evidence is often not collected and therefore lost as observable effect of AM's adoption. Consequently, it can be said that loss of visible outcomes of AM's adoption lower AM's observability, because of high occurrence of optional innovation-decisions.

⊕/⊖ **P XII**	Physician's optional innovation-decisions for one-time AM applications have a negative effect on observability of AM in the medical industry.	

5.2.3 Analysis: Social Structure and System Norms

Interviewees mention apparent differences in nations' development of AM in the medical industry due to various differences such as regulation, funding or research environment. Public private partnerships (PPP's) are seen as bridge for this gap between funding and research. Equally, Szücs and Zaring (2014) argue that university – industry – government relationships, so-called triple helixes, are very important for the diffusion of innovative technologies. They studied Sweden's relationship between the agglomeration of high-technology industries and government-industry cooeperation and found that technology clusters emerge mostly where these triple helixes are apparent. In accordance with that, Kaufmann and Tödtling (2001) found that science-industry cooperation is important for innovtion activities within a system, yet are still rare compared to industrial cooperation. At the same time interviewees state that PPP's are not sufficiently realized for AM in Sweden. Likewise interdepartmental cooepration is insufficient and there is no national center for AM. Farr and Ames (2008) found that weak networks, where members have no shared projects and do not interact frequently, are hindering the diffusion of public health innovations. In general, it is harder to communicate innovations in weak networks, as members lack trust among each other and therefore communication is less likely to reduce uncertainty (Farr and Ames, 2008). Especially for health problems evolved networks are necessary (Goodman et al., 1998).

Interviewees do not only perceive dissimilarity between members of the social system, but also perceive the network structure to be weak and with infrequent exchanges. Engineers, physicians and the industry are not used to cooperate for the development of AM. The higher the similarity between potential adopters, and the stronger the network, the more likely it is that an innovation diffuses (Farr and Ames, 2008; Fitzgerald et al., 2002) Therefore, it can be seen that the need for cooperation of dissimilar stakeholders is effecting the diffusion of AM negatively in the Swedish medical industry.

⊖ P 8	Weak network structure is expected to have a negative effect on the diffusion of innovations in the medical industry.	Supported

Additionally, another finding has been made for system norms in the medical industry. Interviewee's mention that a high safety-orientation compared with conservatism and skepticism against innovations is hindering the diffusion of AM in the medical industry. Interviewed AM vendors, physicians and medical researchers all state so. Medical professionals also do not seem to perceive it as an issue that AM is not diffused, as the increased adoption of innovations is not their primary concern when compared to patient-safety and caution. Strong norms can benefit or hinder the diffusion of an innovation, depending on how the systems norms are aligned with the innovation (Rogers, 2003). Similarly, Nedlund and Garpenby (2014) found that Sweden is considered to have a high use of medical technologies and a regular adoption of innovations, but that this adoption varies between technologies. Therefore, the topic of values has to be seen more nuanced. A generalizable finding about whether physicians are blocking AM due to conservatism or whether that is just perceived in this context "not to be fast enough" cannot be made. After all the subjective speed of how fast an innovation has to diffuse in a social system varies between members and would have to be researched more to get a conclusive finding (Greenhalgh et al., 2004; Rogers, 2003).

5.2.4 Analysis: Communication Channels

Mass media had the least impact on diffusion. This is in accordance with Rogers (2003) who describes the knowledge through mass media, as awareness knowledge, with the farthest reach yet the lowest impact. In the case of the Swedish medical industry, targeted media channels such as journals, clinical documents and industry reports are also seen as more appropriate for the creation of awareness knowledge compared to mass media. Supporting this finding, Valente (1996) found in a restudy on medical innovations that mass media can establish awareness, targeted media is suited for awareness generation, and interpersonal channels lead to diffusion. Also in the case of AM, interpersonal channels in the form of conferences are seen as the most important channel for the diffusion of AM in the medical industry. This is also supported by theory suggesting that interpersonal channels are more effective in the persuasion of potential adopters, as recommendations by previous adopters are more effective than other communication channels (Baptista, 2001; Roman, 2003). Moreover, Bownson et al.

(2013) found that targeted media are used to show the attributes of an innovation to peers in the medical industry and then clarified with interpersonal communication.

The link between the increased use of interpersonal communication and increased diffusion of AM has been mentioned by interviewees and scholars (Brownson et al., 2013). Therefore, interpersonal communication is seen as positively related to the diffusion and sufficiently used for in the Swedish medical industry.

⊕ P 9	Use of interpersonal communication is expected to have a positive effect on the diffusion of innovations in the medical industry.	Supported

Another observation has been made regarding communication channels. A reason for the use of certain communication channels cannot only be sought in the system itself, but also in the innovation that is communicated (Brownson et al., 2013). Here, it has to be noted that medical practices are often rather detailed and critical in their use and require more careful planning (Coiera, 2006; Tang et al., 1996). Given the high complexity of AM and the complexity of medical practices, it can be assumed that AM applications for medical devices are complex innovations. Senescu, Aranda-Mena and Haymaker (2013) found that with increasing complexity in projects, also communication problems increased and more interpersonal communication was necessary. Similarly physicians state that they need the interpersonal communication and the touch-and-feel with the device to be able to comprehend AM. In general it can be said that the greater the complexity of an innovation the higher the uncertainty regarding its adoption for potential adopters. Fidler and Johnson (1984) found that interpersonal communication channels are better to reduce uncertainty than mass media, as the communication can meet specific needs and questions of potential adopters, as well as incorporate immediate feedback. Given this, there seems to be a link between the complexity of an innovation and the suitability of the communication channel. As interpersonal communication channels are more suited for complex innovations following proposition can be made:

⊕/⊖ **P XIII**	The higher the complexity of an innovation, the more interpersonal communication channels are used for its diffusion.	

5.3 Summary of the Results

Previously made propositions have been supported or refuted in the analysis. Moreover, several additional propositions have been made based on the findings (Table 5). Those findings are summarized before they are discussed in the following.

Additive Manufacturing Factors		
⊕ P 1	AM's high relative advantage in low volume production is expected to have a positive effect on its diffusion.	Supported
⊕ P 2	AM's high trialability is expected to have a positive effect on its diffusion.	Supported
⊕ P 3	AM's high observability for the production of otherwise impossible products is expected to have a positive effect on its diffusion.	Refuted
⊖ P 4	AM's high complexity is expected to have a negative effect on its diffusion.	Supported
⊖ P 5	AM's low compatibility is expected to have a negative effect on its diffusion.	Supported
Medical Industry Factors		
⊕ P 6	Physicians as opinion leaders are expected to have a positive effect on the diffusion of innovations in the medical industry.	Refuted
⊖ P 7	Authoritative innovation-decisions are expected to have a negative effect on the diffusion of innovations in the medical industry.	Supported
⊖ P 8	Weak network structure is expected to have a negative effect on the diffusion of innovations in the medical industry.	Supported
⊕ P 9	Use of interpersonal communication is expected to have a positive effect on the diffusion of innovations in the medical industry.	Supported
Discovered Factor		
⊖ P X	High levels of re-invention for AM have a negative effect on its diffusion in the medical industry.	
Interrelated Factors		
⊕/⊖ P XI	Decrease in governmental funding for AM leads to an increase in industry-university cooperation in the medical industry.	
⊕/⊖ P XII	Physician's optional innovation-decisions for one-time AM applications have a negative effect on observability of AM in the medical industry.	
⊕/⊖ P XIII	The higher the complexity of an innovation, the more interpersonal communication channels are used for its diffusion.	

Table 5: Summary of the Results

Resulting from the analysis, not only relationships between factors and their effects on the diffusion of innovations can be found, but it becomes apparent that several of the factors are interrelated as well.

For this reason, the next chapter expands upon the diffusion of innovations theory, discussing interrelations among the factors.

5.4 Interrelations between the Factors Influencing the Diffusion of Innovations

The systemic view on the diffusion of innovations has clearly shown that factors cannot be analyzed isolated from each other, but that they have to be seen in interrelation. Thereby, factors attributed to the innovation interact with factors that are inherent to the social system. This not only shows that the diffusion of an innovation is context dependent, but also that factors can affect each other. These interrelations have been shown in the relationship between (1) opinion leaders' efforts and social structure, (2) innovation-decisions and observability, as well as (3) complexity and communication channels.

(1) A decrease in opinion leaders supporting activities in the social system leads to changes in the structure. Change agents in the form of AM vendors, replace their role. This change in engagement leads to a structural change in networks. More PPP's emerged due to the lack of sufficient government engagement. Here it can be clearly seen that the actors of the system members can shape the structure of the system itself and thus influence diffusion of an innovation through an indirect effect.

(2) The focus on optional innovation-decisions affects the observability of innovations, as the innovation itself is applied differently. In the case of AM in the Swedish medical industry, information about adoption is lost as individuals decide for individual applications instead of the certification of new products. It can be seen that the decision of how to adopt an innovation can affect the diffusion and perceived factors of the innovation itself such as in this case observability. System factors do not actually have to change the innovation physically, but only have to alter the perception about it or alter the level of information available and thus increase, or decrease, the level of uncertainty about the innovation.

(3) Interpersonal communication channels are more appropriate to communicate more complex innovations. Thus the complexity of the innovation influences the communication channels used to communicate about it. In the case of AM it clearly shows that physicians need some interaction and time to address their concerns to be able to understand the innovation.

Uncertainty plays a major role for this discovery. The higher the complexity, the higher is the uncertainty of how to use the innovation adequately. As a result, communication channels that are more suited to the transportation of content are needed, which in turn makes some channels more viable than others. Therefore, it can be seen that also the attributes of an innovation can alter the ways how individuals interact and communicate with each other in a social system, and thus affect diffusion.

These interrelations show that factors have direct effects on diffusion, as well as indirect effects on diffusion that are diverted from direct links to other factors for the diffusion of innovations (Figure 8).

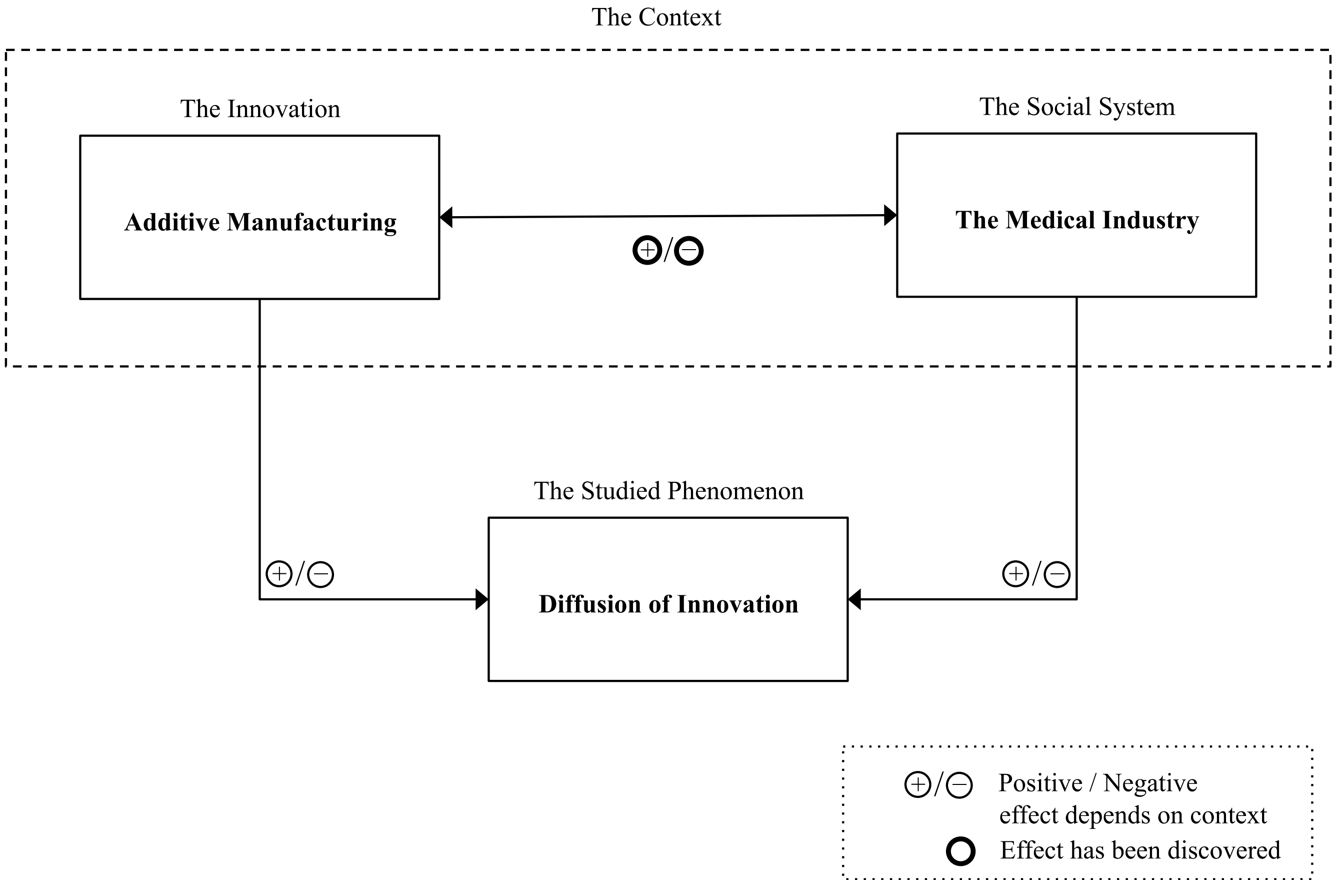

Figure 8: Interrelations between the Factors Influencing the Diffusion of Innovations

Not only could the previously stated propositions be supported or refuted but also several additional propositions have been found. To illustrate the previously stated factors and their effects, as well as newly found interrelations, an integrated framework shows the results of the study (Figure 9).

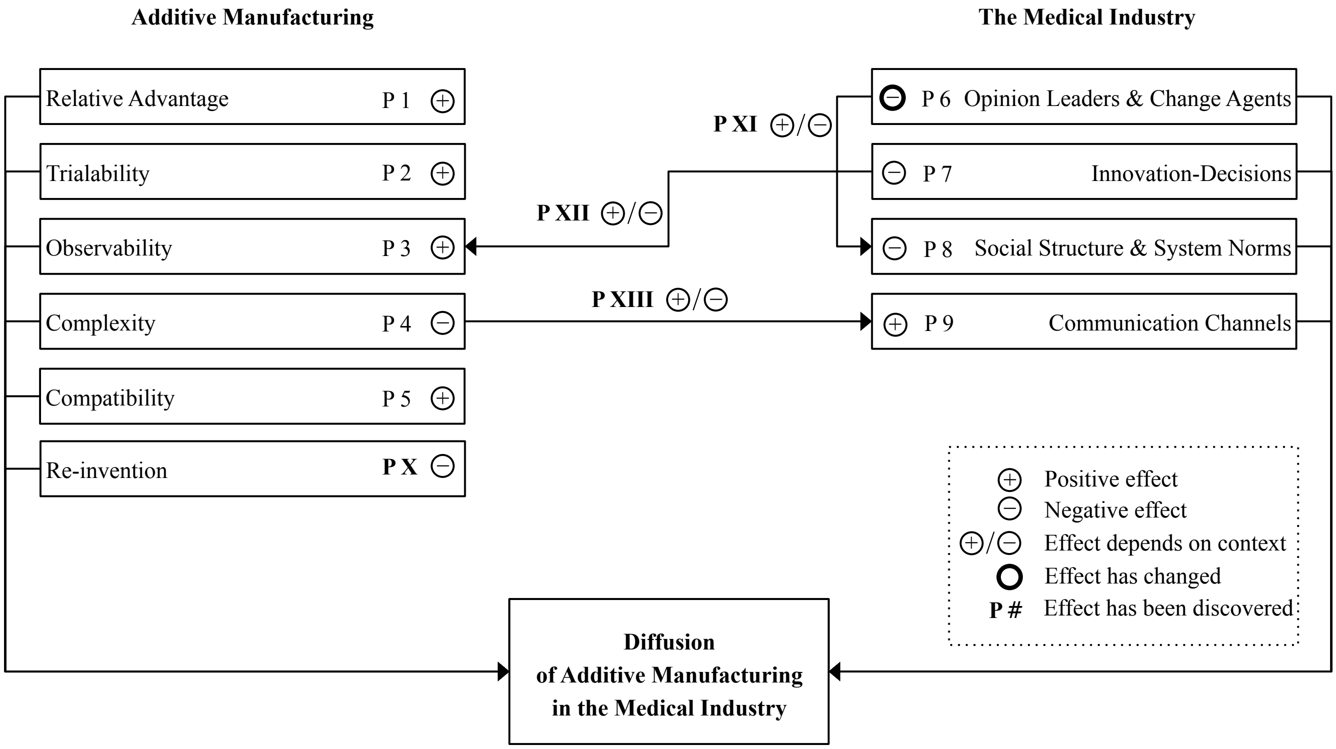

Figure 9: The Integrated Framework

6. Conclusion

The following chapter shows the study's theoretical (6.1) and managerial relevance (6.2), before it closes with recommendations for further research (6.3).

6.1 Theoretical Contribution

The objective of this study is to answer the research questions:

> *What are the factors influencing the diffusion of additive manufacturing in the medical industry?*
>
> *How do these factors affect the diffusion?*

To answer the research questions a qualitative, exploratory study with the help of semi-structured interviews has been carried out in the Swedish medical industry.

To answer the first question, it has been analyzed what factors for the diffusion of AM are present in the medical industry. Therefore, factors' existence has been tested, based on Rogers' (2003) initial factors influencing the diffusion of innovations. Beyond that, the factor re-invention has been added as one of AM's inherent attributes that is affecting its diffusion. Given that re-invention substantially affects potential adopters' perception of an innovation, the extension of the framework creates a more realistic picture. This extension creates a theoretical contribution, as re-invention has previously not been included, yet is a major factor influencing uncertainty among potential adopters. The social system's factors likewise, were found to be present and have an effect on diffusion.

To answer the second question it had to be analyzed how these factors affect AM's diffusion. It has been analyzed whether the aforementioned factors affect AM's diffusion negatively or positively. AM's relative advantage and trialability have a positive effect on its diffusion in the medical industry, whereas observability, complexity, compatibility and re-invention have a negative one. For the system factors of the medical industry solely the use of interpersonal communication channels affects the diffusion of AM positively. Opinion leaders' and change agents' efforts, innovation-decisions and social structure and system norms were all found to be negatively related to the diffusion of AM in the Swedish medical industry. Resulting from that, it has been proven that the contextual factors affect diffusion.

Additionally, attributes of the innovation and the factors of the social system are not only affecting the diffusion itself, but are also affecting each other. Factors influencing diffusion are clearly interrelated, which could be found in the relationship between opinion leaders' efforts and social structure, innovation-decisions and observability, as well as complexity and communication channels. Previous research just looks at the factors as independent variables affecting diffusion. Therefore, this study contributes to the understanding of diffusion of innovations theory and highlights the need for more studies from a systemic perspective to explain context-dependent factors and interrelations between factors.

These findings clearly show that the analyses of the diffusion of innovations should be executed from a systemic perspective. The static view of single factors cannot explain the complex phenomenon of how innovations diffuse in a social system. Here the interplay between the innovation's attributes and the social systems' factors are clearly providing a more thorough explanation of how the factors are affecting the diffusion of innovations.

6.2 Managerial Relevance

The study's results have generalizable, as well as context-dependent managerial relevance. Technology innovation is often seen as the driving force behind nations' increase in medical spending and an efficient diffusion of medical technology is sought by government officials (Grebel and Wilfer, 2010; Hashimoto et al., 2006). Therefore, an increased understanding of how innovations diffuse is beneficial for governmental stakeholders to reduce costs and attain effectiveness in technology diffusion. Additionally, the study sheds light on the perception of AM's attributes among potential adopters, which is valuable for AM vendors that seek to diffuse their technology. The study clearly shows what reduces the medical professionals' uncertainty towards AM and gives information about adoption behavior.

Yet, the study also has to be seen in its social context, the Swedish medical industry. The study's findings have contemporary and immediate value, given the increased attention for AM in Sweden. In November 2014 VINNOVA (2014) published a "*Swedish Agenda for Research and Innovation within Additive Manufacturing and 3D Printing*" together with multiple stakeholders from industry and academia. Their goal is, amongst others, to increase the awareness for AM, among the public and regarding business opportunities. This is essentially the diffusion of AM. Given this, the results of our study can be reused in their actual context and highlight the adoption behavior in the Swedish medical industry.

6.3 Recommendations for Further Research

This study has shed new light on the importance of the systemic view for the diffusion of innovations. Factors clearly have to be analyzed together and not individually, to make interrelations visible. Given that interrelations between factors have been found to affect the diffusion of innovations, future research should look at the contextual factors when the chosen unit of analysis is the system.

Furthermore, the findings of interrelations between opinion leaders' efforts and social structure, innovation-decisions and observability, as well as complexity and communication channels, have to be researched for their generalizability. Beyond that, it should be researched whether interrelations between the system's and the innovation's factors are generalizable for all contexts. Found effects, such can otherwise just be context-dependent. Thus, those links have to be proven with more empirical evidence.

The integrated attribute of re-invention has to be tested for its generalizability as well. It has to be examined, whether the effect of re-invention is specific to the diffusion of AM in the medical industry, or whether re-invention is related to the uncertainty of an innovation in general.

The final recommendation concerns the methodology used. Even though relationships, effects and interrelations could be shown, the impact of those relationships and effects could not be shown with purely qualitative data. Consequently, a quantitative next step to assess the impact of the factors for the diffusion of innovations is recommended.

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Appendices

Appendix I: Questionnaire

General introductory questions:

- When were you first introduced to the topic AM and how?
- Why and when was AM adopted in your individual/organization context? How was it previously?

I. Perceived attributes of innovation

1. Relative advantage

- Did you perceive AM in contrast to the old process to be faster, cheaper or yielding a higher product quality?
- To what extent was the status aspect of AM important in adopting the technology?
- Was the threat of competition an important factor of consideration?
- What are the prime incentives that steer adoption for AM?

2. Compatibility

- How easy was/is it to integrate the new manufacturing process with AM in the processes at your organization?
- How compatible was (and is) the AM technology with current way of working?
- How was AM first positioned on the market? How has that positioning changed since then?

3. Complexity

- How complex was/is it to learn AM? Did/do you need to learn new capabilities and skills?
- Did/do partners have problems with the implementation of AM? Was/is it technologically complex?

4. Trialability

- How difficult was/is it to try out the new production with AM compared to other processes?
- Is the trialability an advantage of AM compared to other processes?

5. Observability

- How easily did/do adopters see a shift in the output through the adoption of AM?
- Was it considered a value-adding innovation from the beginning?

II. Opinion Leaders and Change Agents

- Where you approached by anyone that wanted you to switch to AM?
- Were or are there any particular organizations and individuals that try to push (or hinder) AM out in the industry?

III. Type of innovation decision

1. Optional decision

- Was it a decision inside the organization (CEO, etc.)?
- Was the decision forced by any events, competitive pressure?

2. Collective decision

- Did a parent organization, industry association or partner company influence the decision?
- Was the decision to switch to AM done with other stakeholders together?

3. Authority decision

- Was the decision to adopt AM as new technology made due to any new requirements or other regulation and laws?

IV. Social structure and system norms

- Was AM rather spreading in certain expert or company circles faster?
- Where/are there any differences among countries?
- What do you think about the propensity for innovation in the medical industry?

V. Communication channels

- Where did you hear about AM for the first time? Which channels are currently used (the most)?
- How do you think it will develop in the future?

Appendix II: Data Analysis Process

Part 1/3

Factor	Category	Codes	Quote	Quote ID	Interview ID
Perceived Attributes	Relative Advantage	Competition	*"AM and castings could in theory be each other's competitors, but at the moment they do not really overlap as AM primarily is used for titanium detailes - and in Sweden titanium casting is not conducted, hence no direct competition."*	573	NGO_Inter-viewee_5
		Cost	*"Wherever you come with 3d scanning models everyone is utterly interested but most people are a little bit deterred by the price."*	448	Private_sector_Interviewee_2
		Customization	*"You don't have to make all the manual labor and you have a perfect customized fit."*	452	Private_sector_Interviewee_2
		Speed	*"Sweden should research this from an innovation, productivity standpoint. Basically bring this technology into the lean production phase, in the sense of e.g. producing 1000 pieces at the same time, but where each piece is different. This is not mass production, it is volume production. And for this we in Sweden need printers for research, in order to catch on with the others; to study what parameters are important, which ones should be focused on and how they affect production. And now we are back in Catch 22; we do not receive funding to invest in equipment facilities. This is the biggest worry for the Swedish institutes. We instead rely on the benevolence of the suppliers, but not everyone has that opportunity."*	569	NGO_Inter-viewee_5
	Trialability	Trials	*"The trialability and customization is a very nice advantage for the doctors. You can try very different implants and look what feels better."*	453	Private_sector_Interviewee_2
	Observ-ability	Hype	*"In 2007, there was no mention whatsoever of 3D printing on Gartner's "Hype Curve". In 2008 it emerged on the first part of the curve, and it remained in the same place during 2009, 2010, 2011 until it got a big lift in 2012 and peaks. 2014, by june, it had found its place into industrial applications. So it has been a rather quick trip towards the "Plateau of Productivity" phase."*	568	NGO_Inter-viewee_5
		Technological Readiness	*"... some applications could be done AM but the technology is just not up to the task."*	468	Private_sector_Interviewee_2

Part 2/3

Factor	Category	Codes	Quote	Quote ID	Interview ID
Perceived Attributes (cont.)	Complexity	Education	*"Educational programmes are missing on most levels for AM, including the highest level. There are plenty of educations for design of appearance and shape, but not for material properties such as strength, strain, and safety."*	577	NGO_Inter-viewee_5
		Engineering Skills	*"Today, the ones who do handle the printers are either self-taught, or the companies hire highly educated individuals who in earnest are overqualified for this task. So there is a lot lacking on the educational front for AM. "*	579	NGO_Inter-viewee_5
		Understanding	*"There is a discrepency between what [policymakers] consider to be important and how they act on it, and how much they talk in favour for it. Especially compared to how it is prioritized in Germany and the UK."*	576	NGO_Inter-viewee_5
	Compat-ibility	Mental Change	*"One of the technicians fainted when he first saw the applications of the technology."*	426	Private_sector_Interviewee_2
		Process Change	*"Before these technologies were there, you had to bend the model by hand which took a long time and it would not be accurate and also would weaken the material."*	451	Private_sector_Interviewee_2
	Adjacent Technology	Development	*"What makes the funding issue a bit messy is that 11-13 strategic innovation programs have been approved by Vinnova so far, such as "LIGHTer", "Metalliska material", "Produktion2030", "Innovair", etc. These programs all include the possibility to seek projects that contain 3D printing. It's a [...] general possibility to insert 3D printing within the projects for the above mentioned programmes (e.g., using AM for development of new light-weight applications within the LIGHTer programme). But so far it has been a poor yield for the projects that applied. Vinnova considered the applications to be peripheral to what was asked for in the announcement. So this has been a hinderence for the ability to focus on AM."*	575	NGO_Inter-viewee_5

Part 3/3

Factor	Category	Codes	Quote	Quote ID	Interview ID
Opinion Leaders and Change Agents	Opinion Leader	Clients	*"Nothing happened in 8 years, until [x] received a small grant for a pre-study in the autumn of 2012 [from Vinnova]. That is also when the entire hype exploded around the technology, and Obama talked about it in his State of the Union speech."*	567	NGO_Inter-viewee_5
Innovation-Decisions	Authorit-ative Decision	Application	*"We employ an technology development scale called TRL, where 1 on the scale is basic research, and 5-6-7 is research that can be implemented in the industry by tomorrow. 8-9-10 is R&D conducted on site at the companies. [Vinnova funds research that is between 2 and 8.]"*	571	NGO_Inter-viewee_5
		Procurement	*"Hospital management are not the decision makers. The head of department is the decision maker. If you can prove especially economical benefits, they would not be hesitant."*	458	Private_sector_Interviewee_2
		Regulation	*"The regulatory demands are very rigid."*	443	Private_sector_Interviewee_2
	Optional Decision	Physicians Decision	*"It is no problem to get a customized implant. [...] Many colleagues contact me after they found a paper I have written. Its just a few clicks away."*	472	Private_sector_Interviewee_2
	N/a	Substitutes	*"Standard procedures will still hang on for a long, long time but the AM technologies are definitely concomitant."*	467	Private_sector_Interviewee_2
Social Structure and System Norms	Social Structure	Private-Public-Partnerhsip	*"The company [x] are very easy to work with and are in the partnership, so they give us better prices for anatomical models and train us on how to work with it."*	431	Private_sector_Interviewee_2
	System Norms	Conservatism	*"Doctors do not want to rely completely on the company to do the design themselves. Young doctors design STL files themselves and send it to the producers to maintain control of the model."*	455	Private_sector_Interviewee_2
	Regional Clusters	International Cooperation	*"The government [agency] requested a multidisciplinary [in order to receive funding]. One project was even across all the Nordic countries with people from mainly technical*	429	Private_sector_Interviewee_2
Communica-tion Channels	Inter-personal Commun-ication	Meetings	*"Meetings where many colleagues meet have the greatest impact. You have to feel it with your hands when you touch a model. That makes the doctors interested."*	461	Private_sector_Interviewee_2

Appendix III: Index of Interviews

Name	Sector	Occupation	Company / Institution / Organization	Geographical location	Date of interview	Duration of interview (min)
Jukka Lausmaa	Academia	Associate Professor	Gothenburg University, Department of Biomaterials	Gothenburg	2015-01-26	60
Casper Rosén	Private sector	Sales and Service Technician	3D Center	Västervik	2015-01-28	n/a
Ralf Carlström	Private sector	General Manager	Höganäs Digital Metal	Ängelholm	2015-02-06	70
Anders Westermark	Private sector	Associate Professor and Surgeon (specialized in maxillofacial surgery)	Citytandvården and Medimar	Åland, Finland	2015-03-13	60
Annika Strondl	NGO	Research Leader in powder materials and Manager of process development	Swerea KIMAB	Stockholm	2015-03-19	45
Mats Falck	Academia	Field-Specific Director at External Relations Office Cooperation	Umeå University	Umeå	2015-03-17	45
Erik Borälv	Government agency	Programme Manager for Services and ICT Division	Vinnova	Stockholm	2015-03-18	30
Tero Stjernstoft	Government agency	Programme Manager for Industrial Technologies and Innovation Management	Vinnova	Stockholm	2015-03-18	30
Anders Tufvesson	Private sector	CEO	GT Prototyper	Ystad	2015-02-11	50
Reza Kazemi	Private sector	R&D Manager	Dentware Scandinavia	Kristianstad	2015-03-11	50
Marie Alpman	NGO	Science Reporter	Ny Teknik	Stockholm	2015-03-18	30
Malin Hollmark	NGO	Project Leader for Innovation and Growth	Swedish Medtech	Stockholm	2015-01-21	60
Henrik Gradin	Academia	Ph.D. Researcher	KTH, Micro and Nanosystems, and CTMH	Stockholm	2015-01-08	40
Mikael Bäckström	Academia	Ph.D. and Head of Department of Engineering & Sports Technology	Mid Sweden University	Östersund	2015-01-28	90
Jan Sätherlund	Private sector	Director of Education for 3D Technicians	Xenter Yrkeshögskoleutbildning	Botkyrka	2015-03-12	60
Olaf Diegel	Academia	Professor in Product Development	LTH	Lund	2015-04-01	n/a
Joakim Karlsson	Academia	Ph.D. Researcher in Medical Device Technology	SP Technical Research Institute of Sweden	Stockholm	2015-03-13	90
Evald Ottosson	NGO	Founder of SVEAT, and Sales Manager	SVEAT and Protech	Stockholm	2015-03-13	75
Stefan Peter	Academia	Ph.D. Researcher of Strategy for AM, within Strategic Planning and Innovation	University of Paderborn (DMRC)	Paderborn, Germany	2015-02-16	60
Andreas Fischer	Academia	Postdoctoral Researcher	KTH, Micro- and Nanosystems	Stockholm	2015-01-15	30
Fredrik Finnberg	Private sector	Owner and Managing Director	Digital Mechanics	Västerås	2015-02-03	60
Sten Farre	NGO	Senior Researcher of CAD, Construction, Casting Simulation and Preparation	Swerea SWECAST	Jönköping	2015-03-18	50
Mats Falck*	Academia	Field-Specific Director at External Relations Office Cooperation	Umeå University	Umeå	2015-03-17	15
Peter Thomsen	Academia	Professor, Founder and Director of BIOMATCELL	Gothenburg University, Department of Biomaterials	Gothenburg	2015-02-12	100
Stefan Thundal	Private sector	Product Manager and Area Sales Manager	Arcam	Mölndal	2015-01-26	45
Martin Wildheim	Private sector	Product Development Manager	Arcam	Mölndal	2015-01-26	30
Carin Andersson	Academia	Professor, Industrial Production	LTH	Lund	2015-03-20	45
Robert Andersson	Private sector	Owner	Solidmakarna	Nacka	2015-03-12	30
Annika Borgenstam	Academia	Professor of Physical Metallurgy	KTH, Department of Materials Science and	Stockholm	2015-03-18	30
Martin Wildheim*	Private sector	Product Development Manager	Arcam	Mölndal	2015-01-27	30

* Follow-up interview