Webs of Innovation and Value Chains of Additive Manufacturing under Concideration of RRI

D2.1 Literature review

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I AM RRI

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D2.1 LITERATURE REVIEW

ABSTRACT (3 LINES)

This deliverable presents the result of four extensive literature reviews on factors for innovation success in terms of market, strategic and social impact for additive manufacturing.

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Keywords: Literature review, economic performance, (inter)organization level, business level, project level, social performance.

Abstract: Four extensive literature reviews on factors for innovation success in terms of market, strategic and social impact for additive manufacturing were performed where the focus lies on three levels of analysis; (inter)organizational, business model, and project.

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Content

1 Introduction

Additive manufacturing (AM) is not a single technology, it is a bundle of new production technologies offering innovative design and functionality of products and services. Currently there is a large demand for this way of production. The trend of digitalization additionally supports the application of these technologies. However they are not adopted on a large scale in production lines, some mass customized products e.g. in medical applications are on the market. In fact, many companies are currently printing devices and products applying AM. These actors use many different technologies and the question is which of these technologies will eventually be selected in the market.

Technology selection is a phenomenon that has been studied in the literature by various scholars from a diverse range of disciplines and has a remarkable influence on the webs of innovation value chains. These scholars focus on different levels of analysis and focus on different conceptualizations of technology selection. That facts influenced the literature review since that different levels are taken into account, like (inter)organizational, business model, and project while the conceptualizations of technology selection that are discussed in this deliverable include market, strategic and social performance.

This deliverable D2.1 gives a review on the literature on technology selection and arrive at a list of factors for technology/innovation selection. The first study focuses on economic performance and strategic impact at the (inter)organizational level. The second study focuses on economic performance and strategic impact at the business model-level. The third study focuses on economic performance and strategic impact at the project-level. Finally, the fourth study focuses on general factors for AM social performance. In the four studies, different methods were used so that the number of factors found is as high as possible.

This deliverable attempts to give an answer to the question which factors affect economic performance, strategic impact and social performance of webs of innovation value chains according to the literature. Before an answer can be given to that question it should be clear what is meant by these three conceptualizations of innovation success.

Economic performance is measured in a narrow sense in terms of the number of actors with access to involvement with AM, in terms of customers, market share, in terms of number of products sold from suppliers to customers as well as the resulting turnover and profitability. Economic performance thus focuses on the relevant AM webs of value chains, or the "AM-industrial ecosystem". In comparison to economic performance, social performance is assessing the performance of the system in more normative and less monetary terms and social performance studies the effects of the system on more actors than just suppliers/producers and customers alone. In doing so, stakeholders outside the directly involved actors on the supply and demand side of the market are considered. Considerations important for future generations, or EU-citizens that are not customers but are impacted by the behaviour of supply and demand, are also taken into account. In doing so, not only direct economic monetary indicators are used to study the system but also normative aspects that we consider as important for the society at large, now and in the future. Social inclusiveness, for example, indicates how all relevant citizen groups can benefit from, or are not harmed by, the AM-related activities. Sustainability, for example, refers to the ability of the system to preserve our natural environment for future generations. Dissemination of AM is included here in the form of home AM machines, 3D printing courses or degrees associated with AM. Social performance focusses on users, not customers, as users may have access to AM machines through fab labs, makerspaces, universities or industrial labs. Also, the number of users per AM category (clay, plastics, metal) is taken into account. Strategic impact looks at the effect that the relevant AM webs of value chains, or the "AM-industrial ecosystem" have on the EU. Strategic impact, in comparison to economic performance, thus deliberately looks outside the AM industrial ecosystem. Stimulating employment, increasing knowledge intensive and thus high-level activities in the EU, competitiveness vis-a-vis other parts of the world, and effects of the AM webs of value chains on traditional manufacturing activities all represent a kind of strategic impact.

2 AM economic performance and strategic impact at the (inter)organizational level[1]

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2.1 Introduction

Imagine a possibility whereby products and components get printed by machines. This is possible through Additive Manufacturing (AM). The beginnings of AM lie in the early '90s – back then, the technology was known under the name "rapid prototyping" and was mainly used for that purpose (Atzeni and Salmi 2012). Meanwhile, the fabrication of functional and conceptual prototypes has spread across many industries and the use of AM is no longer limited to prototyping as it is also used in the production of final parts. In the past decade, AM became much used in rapid tooling, for example in the fabrication of moulds or die casts.

The European Commission has identified AM "as a priority area for action offering significant economic potential", fuelled by the hope to re-shore production from low-wage countries and foster innovation and growth in the EU. It is recognized that back-shoring will bring back production which is much different from what has been moved to low-wage countries years ago (Timmermans and Katainen 2017). Despite shifts to the so-called service economy, the manufacturing sectors remain very relevant also to developed countries. For example, the manufacturing sector's share in GDP is 38% in Norway, 30% in Germany, 28% in Austria and 26% in Sweden (Steenhuis and Pretorius 2017).

Although AM technological innovation is technologically possible to realize, they have not yet received widespread adoption and the question is why this is the case. The main research question of this part of the deliverable is: What are the factors for innovation success at the (inter)organizational level for additive manufacturing? Success is measured by using two performance indicators; economic performance and strategic impact. We review literature on factors for innovation success for AM.

Section 2 presents the theory, section 3 provides the methodology that was used for each of the literature reviews, while section 4 presents the results. Section 5 provides a detailed discussion in which the results are interpreted. Each of these sections is split up into 4 parts (that are part of the conceptual model presented above); (1) innovation success in terms of market and strategic impact at the project level, (2) innovation success in terms of market and strategic impact at the (inter)organisational level and (3) innovation success in terms of market and strategic impact at the business-model level; (4) innovation success in terms of social impact at each of the three levels. The paper ends with a conclusion.

2.2 Theoretical approach deriving from literature

An important aspect of market and strategic impact is market acceptance. Various scholars from multiple disciplines have focused on factors that affect market acceptance. Evolutionary economics speak of a 'technology shock' when referring to a technology that substantially increases production output (Shea 2019) . Tushman and Anderson (Tushman 1986) show that long areas of incremental change of the core technology of an industry are interrupted by two types of technological discontinuities: competence-destroying and competence-enhancing discontinuities. The former are so essentially different from previously dominant technologies that previously essential knowledge is no longer viable. Based on this thought, Anderson and Tushman (Anderson 1990) introduce the "technology cycle" which is launched by a (1) technological discontinuity after which the variation in product class increases. This (2) era of ferment is followed by (3) dominant design selection and an (4) era of incremental change, which continues until the status quo is disrupted by another technological discontinuity. A well-known

[1] No one else but the chapter authors can be held responsible for the contents in their chapter

example of a dominant technological trajectory is the dominant keyboard layout Qwerty which won over Dvorak (David 1985).

Technology and innovation management scholars borrow the concept of dominant design from the evolutionary economists and study factors that affect installed base of competing designs. For example, Suarez (Suarez 2004) developed an integrative framework including factors for technological dominance. The author proposes that the dominance process consists of five stages – (1) "R&D build up", (2) "technological feasibility", (3) "creating the market", (4) the "decisive battle" and (5) "post-dominance". Suarez categorizes the factors which influence the outcome along two broad groups: "firm-level factors" and "environmental factors", whilst environmental factors are assumed to affect the outcome in two different ways. They can exert their influence both directly and as moderating factors of various firm-level variables. Other scholars also presented frameworks with factors for a technology to become a dominant design, referring to the phase of the decisive battle (Lee, O'Neal et al. 1995, Hill 1997, Schilling 1998, Gallagher and Park 2002).

Industrial and network economists have studied markets that are characterized by increasing returns to adoption and result in single common standards (Katz and Shapiro 1985). In such markets, installed base is a key factor for the success of these standards. Various standardization scholars have studied standards battles and factors for standard success and these factors have been integrated into frameworks. These are all taken into consideration in a more recent and more encompassing framework that is also enriched by means of literature study (Van de Kaa, Van den Ende et al. 2011).

In the 2000s, management scholars have come up with the notion of platforms which enable the creation of smart, connected products (Porter and Heppelmann 2014). Platforms create many interfaces where standards are needed to ensure compatibility of the components. Platforms refer to a group of technologies which function as a base for the functioning and development of other technologies, processes and applications. Many platforms are characterised by two distinct sides who benefit from interaction through the platform (Rochet and Tirole 2003), so that some sort of "chicken and egg" problem is present. Platform owners must address both sides of the market. Two- and multi-sided markets differ in several aspects from traditional markets as firms not only must determine a price level, but also a price structure. Business models in multi-sided markets often include a "profit centre" and a "loss leader' – the video games market, for example, money is often made by means of royalties on video games and the side of the gamers is treated as a loss leader.

Armstrong (Armstrong 2006) proposes three main factors with respect to the pricing structure presented to both sides of the market:

- 'Relative size of cross-group externalities' entails that the one group which offers large positive externalities to the other group will be targeted more extensively (the author names the example of night clubs: Men would pay higher entrance fees as compared to women if we suppose that men benefit more from the interaction than vice versa.)
- 'Fixed fees or per-transaction charges' refers to the choice of relating the fees to performance or charging on lump-sum basis. If payment is based on successful interaction, then then the agent is not as concerned with the performance of the platform with respect to the other side. Thus, some pressure for the platform to get the other side on board is alleviated.
- 'Single-homing or multi-homing' specifies whether an agent uses only one platform (single-homing) or many platforms (multi-homing). Three cases must be considered: (1) both sides single-home, (2) one group single-homes while the other multi-homes, (3) both groups multi-home.

The trend towards smart, connected products creates new possibilities within the realm of platforms (Porter & Heppelmann, 2014). It decreases barriers to entry as companies now can now compete "product-less", such as the company OnFarm, which provides data collection services to farmers and successfully competes with traditional agriculture companies. In the realm of AM, the platform 3DHubs is a prime example of platform, as its value is created through the enabling of interaction between 3D manufacturers (3D printing, CNC machining, injection moulding) and customers with the desire to produce.

Innovation management scholars have studied the concept of innovation adoption. For example, Ortt and Schoormans (Ortt and Schoormans 2004) analyse the adoption of breakthrough communication technologies. Adoption, or diffusion is often depicted as an S-curve: adoption takes off slowly, then the pace of adoption increases and at some point, a maximum is reached. As opposed to the traditional view, the S-curve is only one part of the story and must be extended to capture the pattern of adoption of breakthrough communication technologies. The average time from invention to first market introduction amounts to between seven and ten years, diffusion often takes off ten years after the first market introduction. However, the S-curve often starts 10 years after first market introduction and fails to capture small scale applications that have a significant stake in stimulating wide-scale adoption of the technology. The S-curve is preceded by erratic patters of adoption after the first market introduction. The authors propose three phases: innovation phase, market adoption phase and market stabilization phase, with the last phase being equivalent to the S-curve. Innovation phase and market adaptation phase together account for the pre-diffusion phase.

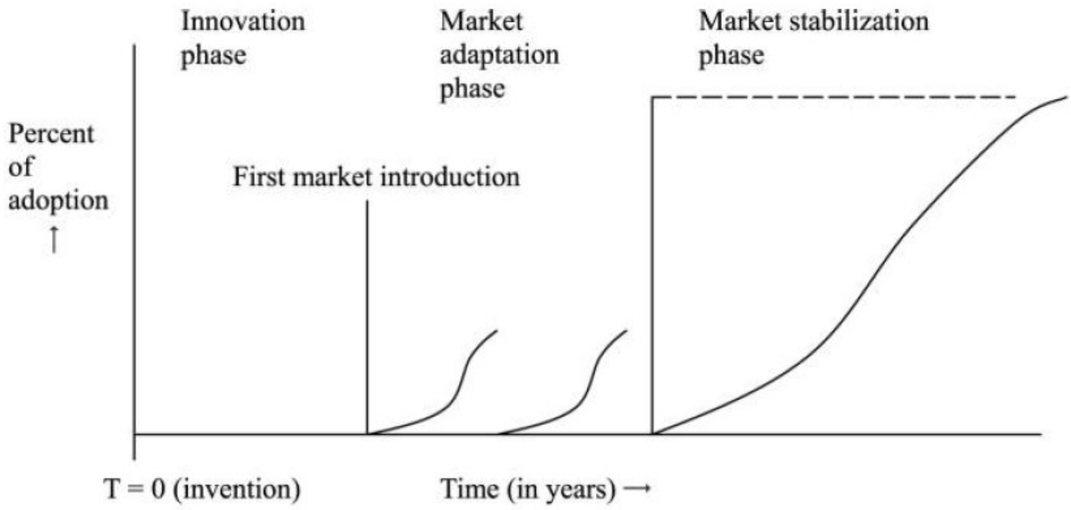

Figure 1: Three phases of technology diffusion (Ortt and Schoormans 2004)

This, however, is not to say that technology diffusion necessarily follows this pattern: it is nevertheless possible, that the technology reaches large-scale diffusion directly after introduction, skipping the market adaptation phase altogether (Tidd 2010). Moreover, innovation and market adaptation phase can vary in length. A long innovation phase might be followed by only a short market adaptation phase and vice versa. And yet, the patterns also differ per industry which Ortt shows based on an analysis of 50 breakthrough technologies in five industries. “Chemicals, metals and materials” as well as “aerospace & defence” were found to have relatively short pre-diffusion phases (11 and 15 years) (Tidd 2010, p. 64). “Pharma & healthcare equipment” is at the other end of the scale with a pre-diffusion phase of approximately 26 years (Tidd 2010, p.64). The other two industries (“telecom, media & internet”, “electronic equipment”) lie in between.

2.3 Method

In order to give an answer to the central research question for the (inter)organizational level of analysis, five studies are conducted. First, we organized a workshop session in which we invited key scholars that can be considered experts that have comprehensive knowledge on the specific level under study in relation to innovation acceptance for the case of additive manufacturing. We asked these experts to come up with a list of keywords that may be used in the literature study.

In the second study, the keywords were transformed into a search string that was used as input for a literature study using the web of science database. This results in a number of articles that were scanned by reading the abstract and it was determined for each article whether the article is relevant for the topic under investigation. Any factors for innovation success in terms of societal and market acceptance are distilled. Subsequently, in study 3, a backwards search (e.g. all articles that are referenced by the article) and a forwards search (e.g. all articles that are citing the article) is conducted using Web of Science.

2.4 Results

2.4.1 Innovations and their impact

Study 1

The workshop that is part of study 1 resulted in a lot of search terms. These were mostly synonyms of the same word. *These include* synonyms for additive manufacturing, synonyms for responsible research and innovation, synonyms for innovation respectively innovation value chain, and keywords relating to success / diffusion, adoption/ technology. *T*he participants also had a brainstorming session on search terms with regard to the main research question. One group suggested a search term structure consisting of specific categories of words and their synonyms. This was enriched by the other groups unstructured suggestions. The search terms were combined into the following search string:

((TS=(3d print OR additive manufactur* OR freeform fabricat* OR additive techniqu* OR additive fabricat* OR layer manufactur* OR general purpose technology OR democratisation of production OR small batch production OR single part production) AND TS=(social OR ecologic* OR ethic* OR value OR rri OR accept* OR responsib* OR sustainab* OR liab*) AND TS=(innovat* OR innovation value chain OR web chain) AND TS=(emerg* technolog* OR diffus* OR adopt* OR success* OR dominan* OR technology innovation system OR complex system* OR supply chain management OR scm OR productiv* OR profit* OR digital* OR automized production OR user centric design OR innovation eco-system OR disagreement OR concern OR open access OR knowledge exchange OR education OR stakeholder network OR industry 4.0 OR diversion OR readiness OR toxicology OR tension OR society OR education OR performance OR business model OR novel* OR share of new products OR health OR automotive OR youngster OR creativ* OR advanced manufacturing technology))) AND TI=(3d print* OR additive manufactur*)*

We have added the condition that either ‘3d print*’ or ‘additive manufactur*’ must appear in the title to exclude publications on the technicalities of additive manufacturing rather than the adoption of it (see the last phrase in the search string). Other than that, the results were restricted to academic articles, books and book chapters.

Study 2

In the second study, the search string of study 1 was applied to the Web of Science. This resulted in a total of 90 entries published between 2007 and 2019 (the search was performed on 23.01.2019). Figure 2 shows the distribution of the entries over Web of Science categories.

Figure 2: Entries per web of science category

Frequently featured journals are Technological Forecasting and Social Change, Journal of Manufacturing Technology Management, Rapid prototyping Journal, International Journal of Production Research and International Journal of Production Economics. Subsequently, these 90 studies were screened for inclusion in the actual study. In a first step, the abstracts of all entries were analysed to exclude studies of purely technological nature. For example, a study by Tonelli et al. (2019) was excluded as it concerns a Rasperry Pi computer which was outfitted with 3D printed parts and opto-electronic components for antioxidant capacity measurement. Also, the entries were screened for non-AM papers (without effect, all papers cover AM). These steps led to the removal of 27 studies from the sample (Figure 3). Subsequently, abstracts were scanned for entries which did not cover factors for success or failure of AM innovations, leading to the removal of 28 entries. The remainder (32 entries) were scanned for which level of analysis they focus on; business model-level, project level and (inter)organisational level. The results of this analysis is shown in figure 3.

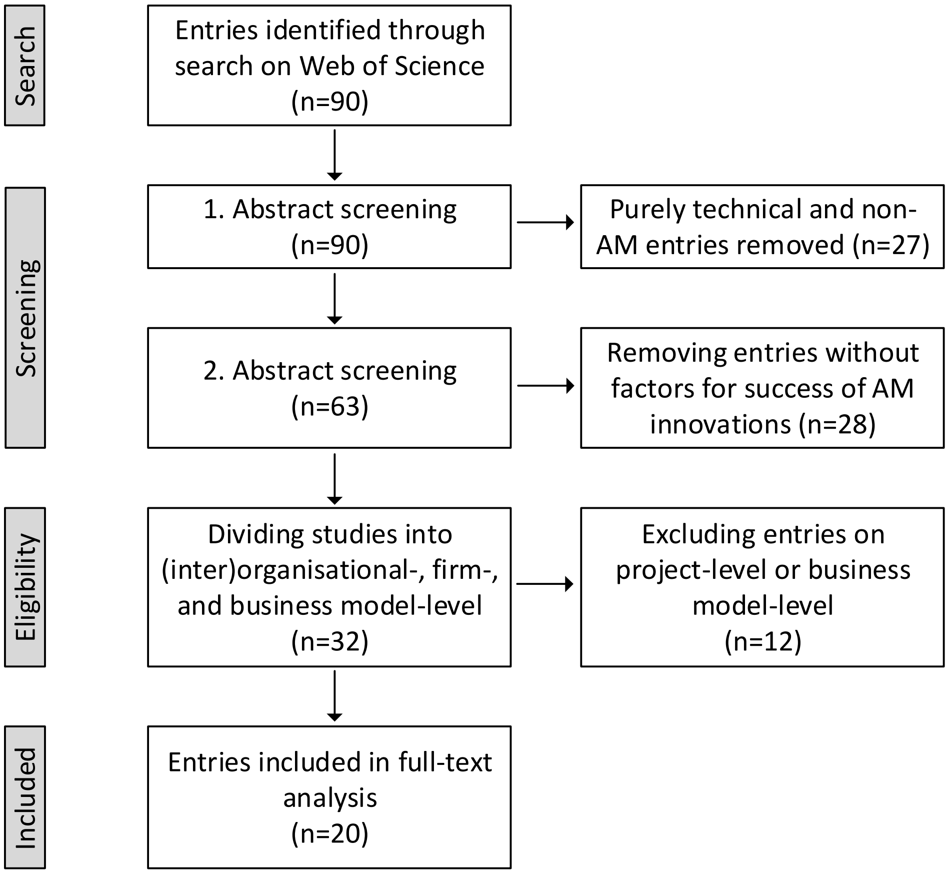

Figure 3: Process of selecting papers for the final literature review (based upon the method of Milchram et al 2018).

This resulted in 3 papers for full-text analysis for the (inter)organizational level (Steenhuis and Pretorius 2016, Lu, Sengupta et al. 2017, Wu, Zhao et al. 2018)(see table 1):

Table 1: results of the literature review for the level of (inter)organizational level of analysis

Reference	**Times cited**	**Citations**
(Lu, Sengupta et al. 2017)	0 / 0	41 / 0
(Steenhuis and Pretorius 2016)	8 / 1[2]	35 / 2[3,4]
(Wu, Zhao et al. 2018)	0	78 / 1[5]

[2] https://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=CitingArticles&qid=14&SID=F5NEfqjVjn-LyOROOuvz&page=1&doc=4

[3] https://apps.webofknowledge.com/CitedFullRecord.do?product=WOS&colName=WOS&SID=F5NEfqjVjnLyO-ROOuvz&search_mode=CitedFullRecord&isickref=WOS:000367861300024

[4] https://apps.webofknowledge.com/CitedFullRecord.do?product=WOS&colName=WOS&SID=F5NEfqjVjnLyO-ROOuvz&search_mode=CitedFullRecord&isickref=WOS:000367861300023&cacheurlFromRightClick=no

[5] https://apps.webofknowledge.com/CitedFullRecord.do?product=WOS&colName=WOS&SID=F5NEfqjVjnLyO-ROOuvz&search_mode=CitedFullRecord&isickref=WOS:000354141600005

Study 3

In table 1 the 3 papers that are the results of the initial literature review are included including the results of study 3; the backwards and forwards search (the times cited and references of each paper are included and after the backslash the number of relevant papers with footnotes to the references are included). New papers that were found through conducting the backwards and forwards search. The footnotes include references to these new papers found. Each paper is analysed in detail for factors for innovation success. Steenhuis and Pretorius (Steenhuis and Pretorius 2016) has conducted an exploratory study and mentions 2 barriers for the adoption of 3d printers by consumers; ease of use and quality of prints. Lu et al. (Lu, Sengupta et al. 2017) has studied 3d printing in the healthcare sectors and came to the conclusion that three factors affect its applicability; regulatory backlog, availability of materials for printing organs, and moral considerations.

Table 2: results of the literature review

	(Steenhuis and Pretorius 2016)	(Lu, Sengupta et al. 2017)	(Wu, Zhao et al. 2018)
"Easy of use"	X		
"Quality of prints"	X		
"moral considerations"		X	
"materials for printing organs"		X	
"regulatory backlog"		X	
"Readiness of concrete printing technology"			X
"Readiness of steel printing technology"			X
"Technology integration"			X
"Potential reduction in life cycle cost"			X
"Project quality assurance"			X
"Better environmental performance"			X
"Potential reduction in construction time"			X
"Availability of resources"			X
"Top management commitment"			X
"Successful cases"			X
"Standard implementation"			X
"Building codes and regulation"			X
"Liability for 3D printed components"			X
"Capability of being modified and demolished"			X

2.5 Conclusion and discussion

The study result in 19 factors for innovation success for AM for both market and strategic impact. However, when examining these factors taking into account the extant literature on factors for innovation success in terms of market acceptance the list of factors does not seem to be complete and therefore we have conducted a separate study in which we studied general factors for innovation acceptance and these were assessed by three panels of experts. In another study we evaluate the extent to which these factors relate to the performance indicators. Finally we evaluate the extent to which the importance and significance of these factors change over time.

2.5.1 General factors explaining market and strategic impact at the (inter)organization level

Factors that affect market and strategic impact (or market acceptance/adoption) come from the contributions made by the scholars mentioned in 2.1 (Gallagher & Park, 2002; Hill, 1997; Lee e.a., 1995; Schilling, 1998). Van de Kaa et al. (Van de Kaa et al. 2011) offers the most complete framework consisting of factors for market success of technology. This is based upon a literature study taking into account contributions from evolutionary economics (Arthur, 1989; Tushman and Anderson 1986; Dosi 1982: 148; Bower and Christensen 1995; Utterback and Abernathy 1975), network economics (Arthur, 1996; David, 1985; Katz & Shapiro, 1985), technology/innovation management (Lee e.a., 1995; Schilling, 1998; Suarez, 2004), and platform economics (Rochet & Tirole, 2003; Suarez & Kirtley, 2012). The factors from the list produced by Van de Kaa et al. (Van de Kaa et al. 2011) have been applied to various cases to test the completeness and relevance of the factors (Van de Kaa and De Vries 2015) as well as to assign weights to the factors (Van de Kaa, De Vries et al. 2014, Van de Kaa, Van Heck et al. 2014, Van de Kaa, Kamp et al. 2017, Van de Kaa, Scholten et al. 2017, van de Kaa, Fens et al. 2018, Van de Kaa, Janssen et al. 2018, Van de Kaa , Fens et al. 2019). Also, various factors have been studied in more depth to try to attempt to understand their specifics (Van den Ende, Van de Kaa et al. 2012, Van de Kaa, Van den Ende et al. 2015, Van de Kaa 2018).

The industry-specific differences regarding diffusion patterns led to research into the factors affecting technology diffusion. Ortt (Ortt 2010) distinguishes between three broad categories of factors regarding the main organisations), the technological system and the market environment.

A recent paper systematically reviewed literature on social acceptance of smart grid technologies and concludes that “moral values can act as factors for smart grid acceptance” (Milchram et al., 2018, p. 6). Searches in Scopus and Web of Science yielded 706 papers of which 49 reported moral values as factors for smart grid acceptance. Environmental sustainability, security of supply and transparency are function as drivers for smart grid acceptance. On the other hand, the study also identifies barriers which are data privacy and security, (miss)trust, health, justice and reliability. Most of these values are relevant for both citizens / consumers and office workers. For companies and society at large, environmental sustainability and security of supply are the most important values, and these are also the main drivers behind smart grid adoption. Other factors seem to have an ambiguous effect: Control or autonomy might hinder acceptance as users might fear to lose control over the system – but then again, the option to override the automated features might be conducive to acceptance. A similar pattern is found with respect to inclusiveness and reliability: increasingly complex systems might intimidate users whilst the same systems also offer more insight, for example by means of a screen.

Combing the contributions from Van de Kaa (Van de Kaa et al. 2011), Ortt (Ortt 2010), and Milchram (Milchram 2018) results in the list of factors mentioned in table 3. Table 4 compared the list of factors found in both literature reviews.

These two groups of factors, together, form the list of factors for success of technological innovation in terms of market acceptance.

Table 3: Factors for success of technological innovation in terms of market acceptance.

Factors
A. Innovator characteristics (demand side)
Customer level of education
Customer resources
Customer ned (necessity to buy)
B. Innovation characteristics (the innovation itself)
Relative technological performance
Compatibility
Compatibility (norms and values)

Factors
Flexibility
Radicalness of innovation
Perceived risk
Communicability
Relative price / cost / effort
Complexity
Reliability
C. Technological environment (physical)
Availability of industrialised production
Complementary goods and services
Enabling infrastructure
Materials supply
D. Innovator characteristics (supply-side)
Financial strength
Brand reputation and credibility
Operational Supremacy
Learning orientation
Network formation and coordination
E. Innovation support strategy
Pricing strategy
Appropriability strategy
Timing of entry
Marketing communications
Pre-emption of scarce assets
Distribution strategy
Commitment (supply side innovator)
Network formation and coordination strategy
F. Other stakeholders
Current customer installed base
Previous customer installed base
Big Fish
Regulator (government, other)
Judiciary
Suppliers
Effectiveness of the development process
Market Potential (sum of all potential customers)
G. Market mechanisms
Bandwagon effect
Network effects and externalities
Number of options available
Uncertainty in the market
Rate of change
Switching costs
Availability of rules and standards
unforeseen (micro) events

Factors
customer adoption process
H. Values and Norms
Environmental sustainability
Data privacy and security
Health
Justice
Control
Inclusiveness
Compatibility

Note. Table created based on Tidd (Tidd 2010) , van de Kaa et al. (van de Kaa 2011), Milchram et al. (Milchram 2018)

2.5.2 Factors and their relation with the performance indicators

Next, the factors in table 3 were assessed by panels of experts with respect to their effect on the three key performance indicators – economic performance, strategic performance and social performance. 19 experts from academia and industry were invited to a workshop and consulted to indicate the relation between the antecedent factors and specific key performance indicators, as this could not be achieved based on literature. The experts were provided with eight categories of factors and a canvas with a table structured along the three key performance indicators (social performance, economic performance, strategic impact). The participants had to assign each of the cards to one key performance indicator (exclusively). The following graph depicts the results of the individual choices:

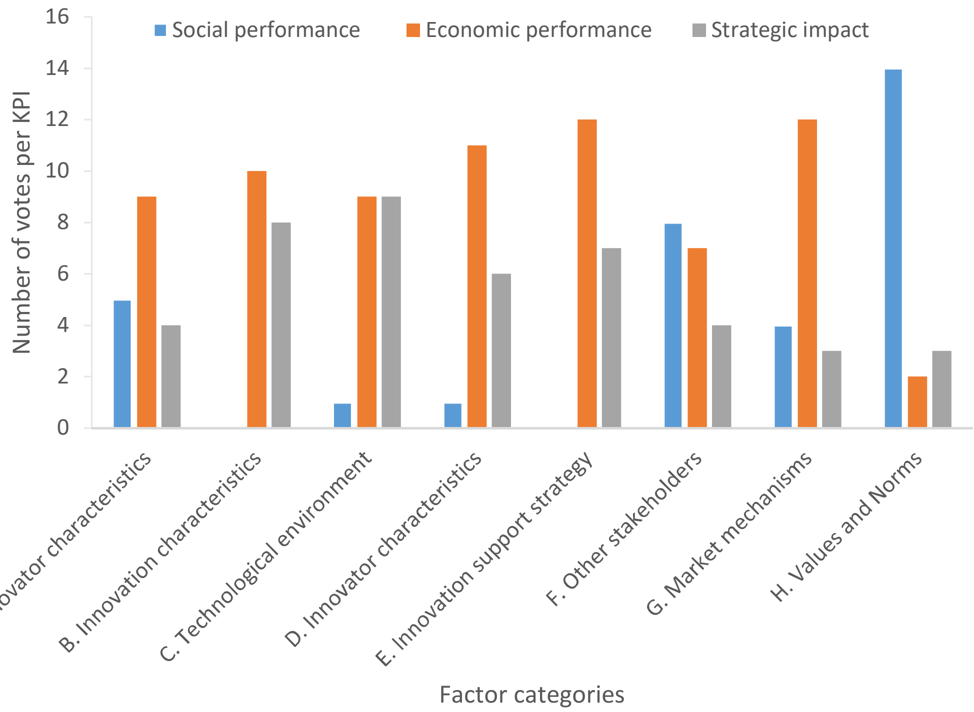

Figure 4: Factor categories assigned to key performance indicators.

From figure 4, it is evident that none of the factor categories was assigned exclusively to one key performance indicators. However, categories B and E were assigned to only two key performance indicators. The factor categories all have a mode except for category C, which is bi-modal.

2.5.3 Dynamic approach

The factors also lend themselves for regrouping along their types of relationships with technology diffusion (Tidd, 2010): (1) independent factors determining the length of the pre-diffusion phase (such as the required infrastructure for telecom products); (2) factors representing necessary conditions for diffusion, making diffusion impossible or very unlikely in their absence (e.g. the absence of a scalable production method as in the case of Dyneema); (3) the combined effect of various factors (such as a technology's fit with the general mission of an organisation); and (4) highly contextual and time-dependent effects of factors (as the presence of war as a facilitator of the diffusion of military technology).

Table 4: General factors for success of technological innovation in terms of market acceptance.

Factors	Idea Generation	Idea and Project Development	Barrier / Stimulus	Diffusion of developed concepts
A. Innovator characteristics (demand side)				
Customer level of education	x	x		
Customer resources	x	x		
Customer ned (necessity to buy)				
B. Innovation characteristics (the innovation itself)				
Relative technological performance	x	x	x	x
Compatibility	x	x		x
Compatibility (norms and values)				
Flexibility	x	x		x
Radicalness of innovation	x	x		x
Perceived risk				
Communicability				
Relative price / cost / effort				
Complexity				
Reliability				
C. Technological environment (physical)				
Availability of industrialised production			x	
Complementary goods and services	x	x	x	x
Enabling infrastructure				
Materials supply				
D. Innovator characteristics (supply-side)				
Financial strength	x	x		x
Brand reputation and credibility				x
Operational Supremacy	x	x		x
Learning orientation	x	x		x
Network formation and coordination			x	
E. Innovation support strategy				
Pricing strategy	x	x	x	x
Appropriability strategy				x
Timing of entry				x
Marketing communications	x	x		x

Factors	Idea Generation	Idea and Project Development	Barrier / Stimulus	Diffusion of developed concepts
Pre-emption of scarce assets	x	x		x
Distribution strategy	x	x		x
Commitment (supply side innovator)	x	x		x
Network formation and coordination strategy			x	
F. Other stakeholders				
Current customer installed base				x
Previous customer installed base				x
Big Fish				x
Regulator (government, other)	x	x	x	x
Judiciary				x
Suppliers				x
Effectiveness of the development process	x	x		x
Market Potential (sum of all potential customers)	x	x	x	
G. Market mechanisms				
Bandwagon effect			x	
Network effects and externalities	x	x	x	
Number of options available	x	x	x	
Uncertainty in the market	x	x	x	
Rate of change	x	x	x	
Switching costs			x	
Availability of rules and standards	x	x	x	
unforeseen (micro) events	x	x		
customer adoption process	x	x	x	
H. Values and Norms			x	
Environmental sustainability			x	
Data privacy and security			x	
Health			x	
Justice			x	
Control			x	
Inclusiveness			x	
Compatibility			x	

Note. Table created based on Tidd (2010) , van de Kaa et al. (2011), Milchram et al. (2018)

2.6 Conclusion

This paper has conducted a comprehensive literature review into factors for innovation success in terms of market acceptance and strategic impact. 19 factors were found to be relevant factors for innovation success at the interorganisational level. A comparison with the factors found in the general study is reported in table 5. I appears that most factors fall under the existing factors known already in the literature. Three new factors can be found though; regulatory backlog, Project quality assurance, and Liability for 3D printed components.

Table 5: General factors for innovation success in terms of market acceptance vs factors for success of AM technological innovation in terms of market acceptance.

	(Steenhuis and Pretorius 2016)	(Lu, Sengupta et al. 2017)	(Wu, Zhao et al. 2018)	Results from literature study 2
"Easy of use"	X			Technological superiority
"Quality of prints"	X			Technological superiority
"moral considerations"		X		Values and norms
"materials for printing organs"		X		Materials supply
"regulatory backlog"		X		
"Readiness of concrete printing technology"			X	Technological superiority
"Readiness of steel printing technology"			X	Technological superiority
"Technology integration"			X	Compatibility
"Potential reduction in life cycle cost"			X	Relative price cost effort
"Project quality assurance"			X	
"Better environmental performance"			X	Environmental performance
"Potential reduction in construction time"			X	Technological superiority
"Availability of resources"			X	Complementary goods
"Top management commitment"			X	Commitment
"Successful cases"			X	Learning orientation
"Standard implementation"			X	Number of options available
"Building codes and regulation"			X	Regulation
"Liability for 3D printed components"			X	
"Capability of being modified and demolished"			x	Flexibility

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3 AM Economic Performance and Strategic Impact at the Business Model Level[6]

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3.1 Introduction

Many scholars in management and business studies have devoted their time and effort to understand the key ingredients to successful business (Casadesus-Masanell and Zhu 2013; Massa, Tucci and Afuah 2017). One of the most common findings postulates that innovation is the engine for growth (Osterwalder and Pigneur 2010). For so long, innovation in product and process is considered to be the main factor for firm's competitive advantages (Teece 2010; Timmers 1998). Although many firms have developed excellent products or services, many of them also experience failure after several years in business. Large and strong firms such as KODAK, Motorola, Nokia, DEC, AEG have lost their significant market share after enjoying successful years of trading (Gassmann, Frankerberger, Csik 2014). The answer to this is relatively simple; those firms fail to adapt their business to the continuously changing market environment (Zott, Amit and Massa 2011). In addition to customers' demand that is naturally dynamic, other factors such as regulation may change whereas new technology is also quickly disrupting the old ones.

Facing those challenges, firms need to build a business by using new and innovative approach. In the past, technology and innovation that was transformed into a marketable product or service was considered sufficient for success. Companies such as Gillette has been known as one example of innovative firms with their capability to innovate constantly. It started with the first creation of a safe razor, Gillette has continued their innovation by introducing different variety of razor blades such as twin blade, four blade and disposable blade. However, history has told us that the abilities to continue innovation activities and rely on the first mover advantage strategy are not enough. In the current business circumstance, the capability to adjust business and adapt to new challenges has been seen as a critical factor to support business' survival and longevity (Zott and Amit 2013; Foss and Saebi 2017). Innovation is now known not only in the forms of product and service but also in the context of business model (Chesbrough 2010). A famous example of business model innovation is shown by firms such as Facebook or google that have disrupted incumbent's market existence or create a new market that had not been existed before. Figure 5 illustrates the potential gain of business model innovation over product and process innovation. The figure clearly shows that most firms after investing a large amount of their resources in developing a product, continue with process innovation as soon as the product has reached a dominant market. However, firms need to create business model innovation to continue their growth cycle and prolong their existence.

[6] No one else but the chapter authors can be held responsible for the contents in their chapter

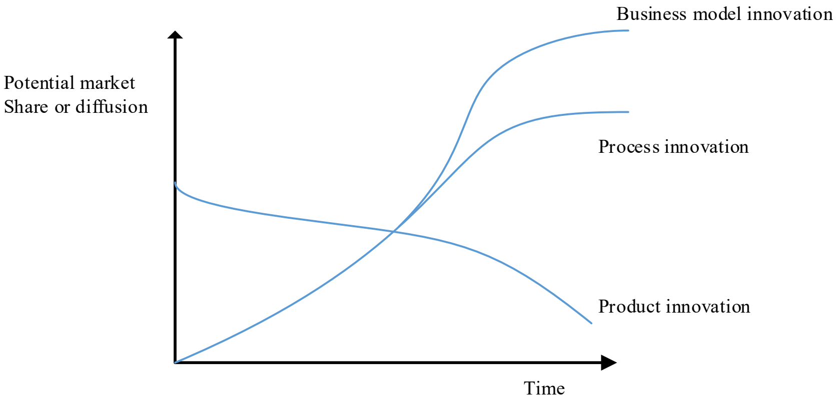

Figure 5: Business model innovation as a complement of product and process innovation

This report aims to examine factors that may contribute to the success of Additive manufacturing (AM) firms from a business model perspective. In the context of developing a product and service based on new technology such as AM, firms need to build a strong case for their business model. In doing so, literature reviews on business model were conducted. Bibliometric analysis was performed to capture the current trend and development of business model literature. Followed with detail analysis on the most cited articles in the business model literature. The analysis was concluded by presenting several important factors that needed to be considered in order to create a successful AM business.

3.2 The growth and the development of business model concept in the literature: Bibliometric analysis

While the term of business model has become a popular term in academics and practice world (Chesbrough and Appleyard 2007; Casadesus-Masanell and Zhu 2013; George and Bock 2011), scholars are still debating the definition of business model and scrutinise factors that may be regarded as the element of business model. The emergence of a new market such as in Asia or Africa and the development of new technologies such as internet and mobile applications have opened a new form of business that has not been existed before (Baden-Fuller and Haefliger 2013). The way of conducting business has also evolved while new firms emerge to replace the old ones. Reviewing more than 7,000 publications during the period of 1980–2015, Foss and Saebi (Foss 2017) show that the number of studies focusing on business model has accelerated (Figure 6).

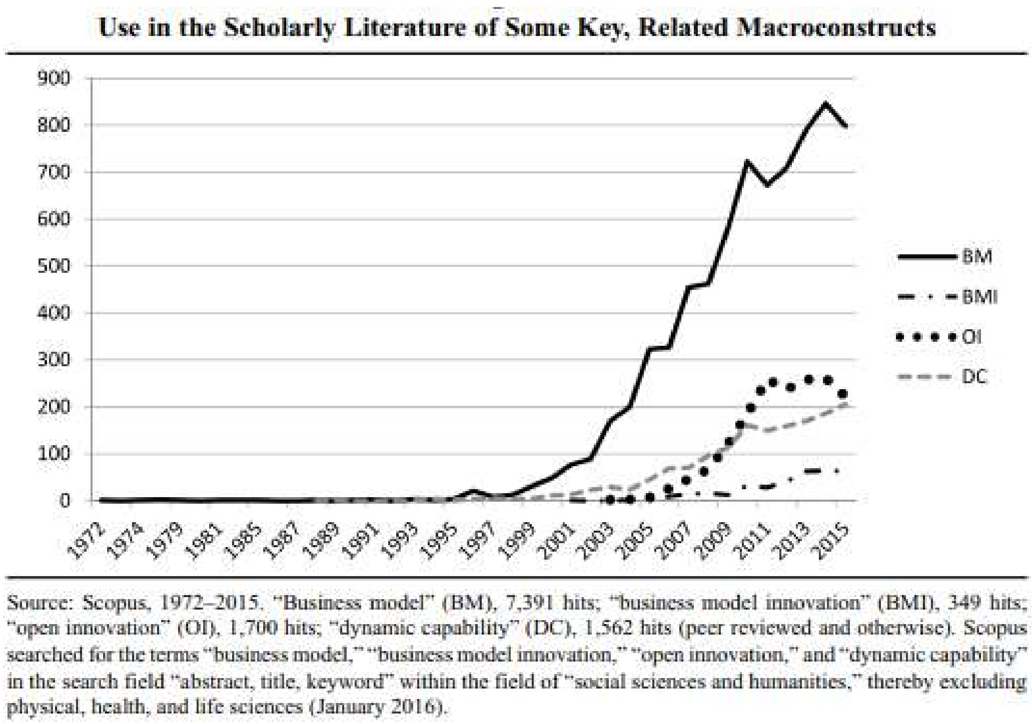

Figure 6: Foss and Saebi (2017)'s illustration on the growth of business model research

In this report, the data was generated using web of science database. The articles were selected if they have the following criteria, namely.

1. The title contains 'business model'
2. The topic of the paper is 'business model' or 'business model innovation'
3. The paper is within business and management field. By doing this, we excluded papers published in other field such as engineering or science.
4. The paper is published at ranked journals (ABS) or listed in Scopus (A and B level)

In total, 907 papers were collected. Figure 7 shows the total publications by years while the total number of citations is presented in figure 8. Overall, both figures show a strong trend of business model literature with the number increasing exponentially since 2010. It seems that the year (2010) is quite significant as many highly cited articles were published in that year.

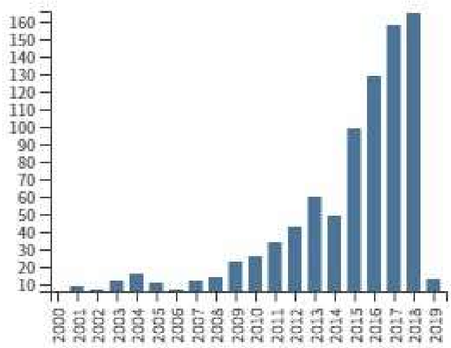

Figure 7: Total publications by year

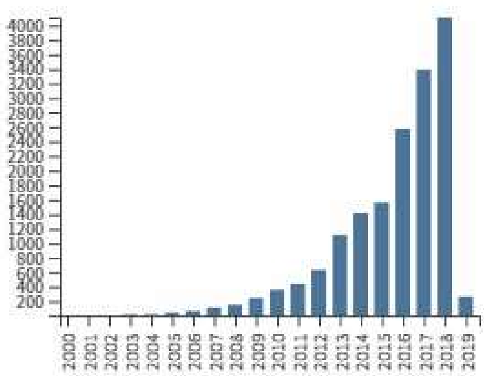

Figure 8: Sum of times cited by year

Table 6 shows the most cited articles in the business model literature. Prominent scholars such as Teece, Chesbrough, Zott and Amit have been influential in defining the field. Both authors have shaped the development of theory and concept of business model. Moreover, other scholars such as Demil, Lecocq, and Christensen have also been known to give a strong contribution to the field.

Table 6: The highly cited articles (web of science)

Title	Authors	Source Title	Total Citations	Average per Year
Business models, business strategy and innovation	Teece, DJ	LONG RANGE PLANNING	1378	71.2
The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies	Chesbrough, H; Rosenbloom, RS	INDUSTRIAL AND CORPORATE CHANGE	1129	62.72
The Business Model: Recent Developments and Future Research	Zott, Christoph; Amit, Raphael; Massa, Lorenzo	JOURNAL OF MANAGEMENT	865	96.11
Business Model Innovation: Opportunities and Barriers	Chesbrough, Henry	LONG RANGE PLANNING	734	73.4
The entrepreneur's business model: toward a unified perspective	Morris, M; Schindehutte, M; Allen, J	JOURNAL OF BUSINESS RESEARCH	621	41.4
Business Model Design: An Activity System Perspective	Zott, Christoph; Amit, Raphael	LONG RANGE PLANNING	583	58.3
Reinventing Your Business Model	Johnson, Mark W.; Christensen, Clayton M.; Kagermann, Henning	HARVARD BUSINESS REVIEW	474	39.5

The fit between product market strategy and business model: Implications for firm performance	Zott, Christoph; Amit, Raphael	STRATEGIC MANAGEMENT JOURNAL	436	36.33
Business model design and the performance of entrepreneurial firms	Zott, Christoph; Amit, Raphael	ORGANIZATION SCIENCE	362	27.85
Business Model Evolution: In Search of Dynamic Consistency	Demil, Benoit; Lecocq, Xavier	LONG RANGE PLANNING	359	35.9
Conceptualizing a sustainability business model	Stubbs, Wendy; Cocklin, Chris	ORGANIZATION & ENVIRONMENT	263	21.92
The business model concept: theoretical underpinnings and empirical illustrations	Hedman, J; Kalling, T	EUROPEAN JOURNAL OF INFORMATION SYSTEMS	257	15.12
Islamic vs. conventional banking: Business model, efficiency and stability	Beck, Thorsten; Demirguec-Kunt, Asli; Merrouche, Ouarda	JOURNAL OF BANKING & FINANCE	247	35.29
Creating Value Through Business Model Innovation	Amit, Raphael; Zott, Christoph	MIT SLOAN MANAGEMENT REVIEW	237	29.63
Business Model Innovation through Trial-and-Error Learning The Naturhouse Case	Sosna, Marc; Trevinyo-Rodriguez, Rosa Nelly; Velamuri, S. Ramakrishna	LONG RANGE PLANNING	236	23.6
Embedding Strategic Agility, A Leadership Agenda for Accelerating Business Model Renewal	Doz, Yves L.; Kosonen, Mikko	LONG RANGE PLANNING	210	21
The Business Model in Practice and its Implications for Entrepreneurship Research	George, Gerard; Bock, Adam J.	ENTREPRENEURSHIP THEORY AND PRACTICE	197	21.89
Business-Model Innovation: General Purpose Technologies and their Implications for Industry Structure	Gambardella, Alfonso; McGahan, Anita M.	LONG RANGE PLANNING	159	15.9
Servitization: Disentangling the impact of service business model innovation on manufacturing firm performance	Visnjic Kastalli, Ivanka; Van Looy, Bart	JOURNAL OF OPERATIONS MANAGEMENT	146	20.86
The utility business model and the future of computing services	Rappa, MA	IBM SYSTEMS JOURNAL	146	9.13
Developing a unified framework of the business model concept	Al-Debei, Mutaz M.; Avison, David	EUROPEAN JOURNAL OF INFORMATION SYSTEMS	145	14.5

Note: the data was extracted from web of science.

In this study, VOSviever and Cinetexplorer were used to perform the bibliometric analysis. The next figure presents the result of co-citation analysis. Co-citation analysis, among the standard methods in bibliometric research, is powerful to visualise the development of a certain field of scholarship (De Bellis 2009). The logic behind the method is when an author cites a paper, the reference shows the source of resources that have been used by the author in develop his/her scholarship. Therefore, it is believed that co-citation analysis shows how past research/studies contribute to the development of knowledge in the field. From the figure below, we identified several prominent articles in the business model literature. Articles from Teece (Teece 2010) and Chesbrough (Chesbrough 2010) were located in the centre of the map indicating that most of other articles in business model cited their articles. It is also important to note that articles from Zott, Osterwalder, Timmers were located located in the periphery meaning that they were not highly cited and connected compared to Teece and Chesbrough.

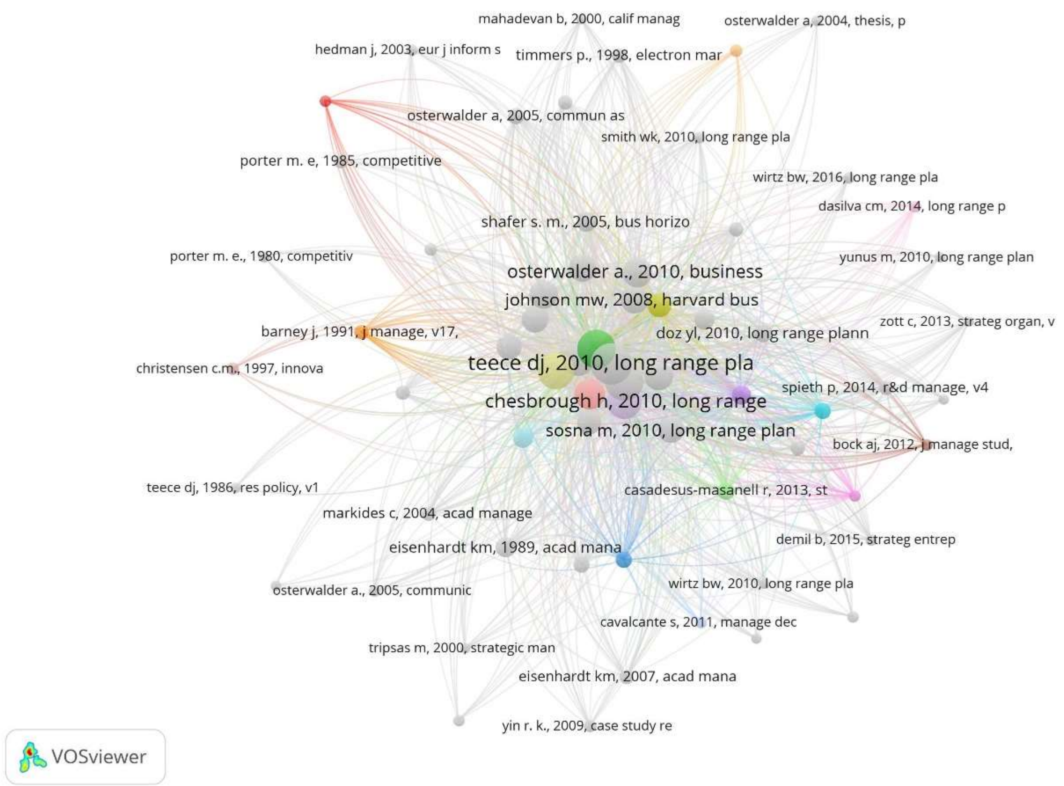

Figure 9: The result of the co-citation analysis

In the next figure, a co-word timeline analysis was performed. Similar to the previous method, in this method, the year the articles were published was considered and visualised (De Bellis 2009). In contrast to the previous analysis that found that the papers from 2010 are important, the co-word timeline analysis shows that papers from Magretta, Amit and Chesborugh in the early 2000 had become a basis for the development of the business model literature. These early studies have been influential in shaping the development of knowledge of business model. In this context, Teece has referenced studies that were closely linked to business model while authors such as Zott, Amit and Osterwalder were not closely linked.

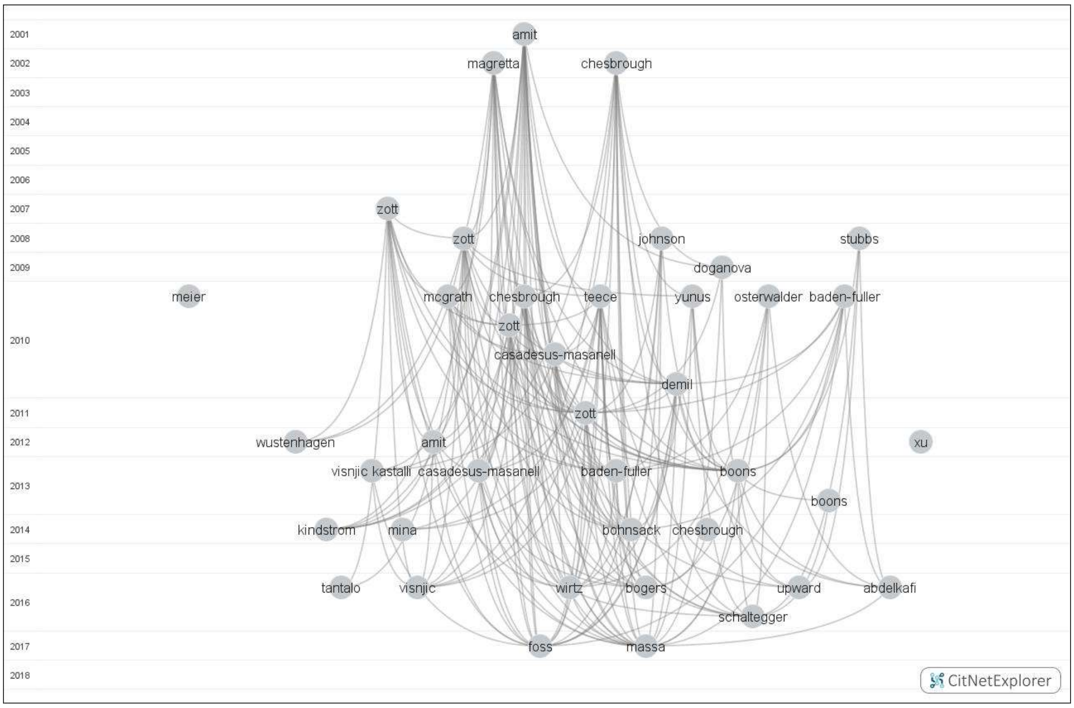

Figure 10: The result of the co-word timeline analysis

The last analysis is co-word analysis. Co-word analysis is similar to co-citation analysis. While in the co-citation analysis, the analysis focuses on papers that are jointly cited, the co-word analysis deals with a set of terms shared by the papers (De Bellis, 2009). In this study, we extracted the keywords of those selected papers and ran the co-word analysis. The finding shows that 'business model' dominated the keyword followed with other terms such as 'business model innovation' and 'innovation'. Overall the figure illustrates that the concept of business model has reached other domains/fields especially in the domains of innovation management, strategy and entrepreneurship.

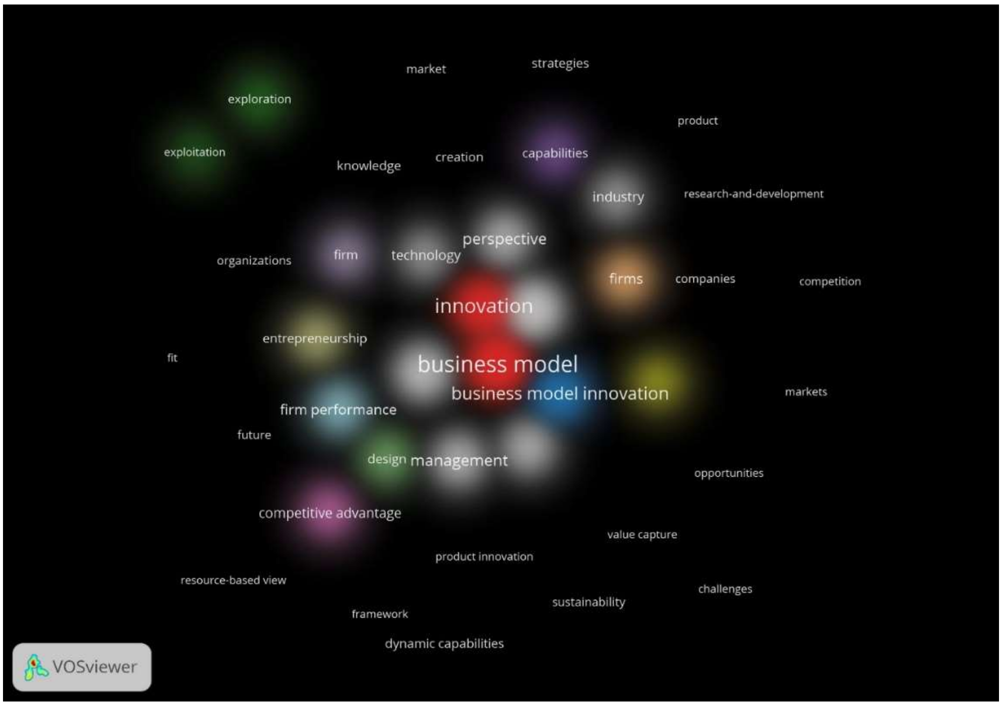

Figure 11: The result of the co-word analysis

3.3 Content analysis of the most cited articles on business model

The objective of this study is to identify factors that contribute to the development of a successful business model in the AM industry. To gain insights into this topic, a literature study based on the most prominent articles in the field will be examined in detail. Based on the bibliometric results several papers reviewing business model, six papers were analysed. These includes:

1. Teece, D.J. (2010) Business Models, Business Strategy and Innovation, Long Range Planning 43, 172-194.
2. Chesbrough, H, and Rosenbloom, R.S. (2002) The Role of Business Model in Capturing Value from Innovation: Evidence from Xeroc Corporation's Technology Spin-off Companies, Industrial and Corporate Change, 11(3), 529-555.
3. Chesbrough, H. (2010) Business Model Innovation: Opportunities and Barriers, Long Range Planning, 43, 354-363.
4. Zott, C., Amit, R., Massa, L. (2011) The Business Model: Recent development and Future Research, Journal of Management, 37(4), 1019-1042
5. Casdesus-Masanell, R, and Ricart, J.E. (2010) From Strategy to Business Models and Onto Tactics, Long Range Planning, 43, 195-215.
6. Johnson, M.W., Christensen, C.M., Kagermann, H. (2008) Reinventing Your Business Model, Harvard Business Review, December.

The first paper is from Teece (Teece 2010) discussing business model in more general although some examples from internet business were used to support his arguments. Teece (Teece 2010) argued that the concept of business model does not have theoretical foundation and has not been examined by any economic theories. As a result, business model as a concept has a loose denotation and potentially may create some confusion. According to Teece (Teece 2010), a difference should be made between business model and business strategy. Business model is about articulating business logic and other evidence to support how firms generate value. In any business model, it is important to put customers at the centre and to develop a viable structure of revenue and costs. Based on this explanation, business model is simpler than firms' strategy as it explains how a company delivers value to their customers. Using examples such as Dell, google and music industry, Teece (Teece 2010) had tried to portray how innovation in products and services should be imbued with innovation in business model. The classic example of razor blade business model shows that a small innovative idea is often powerful enough to generate a significant revenue. Teece (Teece 2010) also discussed several factors that may contribute to the success of business model. First, it is about the ability to create a new business model that is hard to be imitated. In many senses, copying someone else's business model is not hard. The concept of business may be transparent enough to be understood. However, business model includes a new process, new system, and new assets that are not easy to be replicated. For incumbents, there is a barrier to imitate or apply a new business model especially if the new business will potentially destroy their existing business. Another factor that helps create successful business model is the capability to adapt and learn. There is no perfect business model. Therefore, it is important to have the capability to respond to the changes in demand and the dynamic in market while simultaneously adjust the business model. Teece (Teece 2010) provided an example about how Netflix won the battle against Blockbuster. At the beginning, they started with the same type of business – DVD rental business, but later Netflix found a technology to offer a better value to their customers.

The second paper is from Chesbrough and Rosenbloom (Chesbrough and Rosenbloom 2002). The paper examined how business model can be used to explain the way firms capture value in the context of early technology. Using six case studies as an empirical investigation, Chesbrough and Rosenbloom (Chesbrough and Rosenbloom 2002) argued that technology is an effective tool to deliver value to customers. However, possessing technology alone will not guarantee a successful business. Empirical evidence in internet-based business shows that the results varied. Chesbrough and Rosenbloom (Chesbrough and Rosenbloom 2002) offered an explanation that the capability to connect technical competence and economic realisation is the key to create a successful business. To emphasise their point, they used an example in which XEROX used their spin-off to deliver a new value to their customers. The spin-off was not only capable of developing the technology further but they had become successful by detaching from XEROX's dominant logic. Similar to the previous paper (Teece 2010), Chesbrough and Rosenbloom (Chesbrough and Rosenbloom 2002) also discussed the differences between business model and strategy. According to them, the difference lies on the recipient of value. In strategy, value is offered to the stakeholders while in business model, value is created within and for the firms. Moreover, strategy is more analytical and robust with a great deal of information and data involved while business model is more limited and bias toward the early stage of firms' development. In this aspect, business model is developed with a higher degree of uncertainty compared to strategy. Moreover, Chesbrough and Rosenbloom (Chesbrough and Rosenbloom 2002) gave an explanation to factors that contribute to the development of successful business, among others are:

- Value proposition; firms need to articulate their value offering and convince customers to buy their product or service. It is important to define potential benefits of technology and how the technology can address the needs of customers and how customers can value what technology can offer in their own context.
- Market segment; firms need to understand their market and how technology can be used to deliver value specific to a certain market segment. Success in identifying market will result in revenue generation.
- Value chain; firms need to define and create the structure of their value chain in delivering their offers.
- Profit and cost structure; firms need to estimate potential profit and cost given the value proposition, market segment and value chain. This includes how customers will pay, how much they will pay and how overall value can be distributed among firms, customers and suppliers.
- Supply chain; firms need to describe their position within suppliers and customers including potential competitors.
- Competitive strategy; firms need to develop a strategy to maintain their competitiveness over competitors.

The third paper is from Chesbrough (Chesbrough 2010). The paper has a similar approach to the earlier paper (Chesbrough and Rosenbloom 2002) as it still mentioned XEROX company as a practical example of business model implementation. However, in this paper Chesbrough (Chesbrough 2010) emphasised how XEROX's spin-off company, namely3Com utilised the technology that had been developed in XEROX and launched an independent business based on that technology. Another example was given by referring to the changing business in music industry. In the paper, Chesbrough (Chesbrough 2010) pointed out several barriers for establishing new business model. First, the capability of the firms to open their dominant logic and break from their path dependent. Compared to the previous studies on business model, Chesbrough (Chesbrough 2010) emphasised the importance of breaking the barrier and embracing a new way of doing business. However, the process is challenging and therefore, Chesbrough (Chesbrough 2010) argued that firms need to actively experiment with their business model. In the process of adopting business model, it is also important that the firms be flexible and adaptable. Using Sarasvathy's (Saravathy 2001) term – effectuation, Chesbrough (Chesbrough 2010) argued that firms may need to take action and enact a new business even in the condition of limited information. Lastly, adopting a new business model requires a strong and capable leadership. Organisations that shift from old to new business model need to balance their operational activities. Leaders need to be able to manage the process of changes and deliver a better business model for the firm.

The fourth paper is from Zott, Amit and Massa (Zott 2011). Compared to the previous selected papers, this paper benefited from bibliometric analysis and literature review to examine business model concept. According to them, business model literature became popular following the growth in internet business in the mid-1990s. Using EBSCO database, they collected more than 1, 2020 articles in academic journals. They also considered non-academic articles which led them to at least 8,062 articles. Looking on the definition, Zott, Amit and Massa (Zott 2011) concluded that business model has been discussed extensively but with too many definitions. Interestingly, they also found that more than one third of the selected papers do not define the concept clearly. As a result, the lack of clarity in the definition create confusion and divergence of perspective of business model as a theoretical concept. The paper also specifically mentioned that the business model literature has a strong bias toward internet-based business. As a result of this bias, many studies have been conducted in looking how business model works in the context of internet technology and have raised a question regarding the replicability of the concept for another field.

Furthermore Zott, Amit and Massa (Zott and Massa 2011) concluded that business model is about value creation, performance and competitive advantages. In discussing value creation, the author argued that firms have a new opportunity to create and deliver value through digital technology. Citing several previous articles such as Zott and Amit (Zott and Amit 2013), Thompson and MacMillan (Thompson and MacMillan 2010), the authors argued that value creation mechanism should be considered in network perspective involving how suppliers, business partners, distribution channel are used to deliver value to customers. In discussing performance, citing several empirical studies (e.g. Patzelt, Knyphausen-Augseb and Nikol 2008; Afuah 2004; Linder and Cantrell, 2001; Giesen, Berman, Bell and Blitz 2007), they argued that business model plays a central role in explaining competitive advantages and firms performance. Moreover, likewise other papers, Zott, Amit and Massa (Zott 2011) also mentioned about how business model differs from strategy. They concluded that business model is customer-focus strategy where value is created and delivered by the firms.

The next paper is from Casadesus-Masanell and Ricart (Casadesus-Masanell and Ricart 2010). The paper presents the argument that business model is similar to strategy in the sense that the concept of business model refers to a logic of the firms. According to the authors, business model is a reflection of firms' strategy or the outcomes of conducting certain strategy but is not a strategy itself. In addition, Casadesus-Masanell and Ricart (Casadesus-Masanell and Ricart 2010) discussed the term 'tactics'. Tactics refers to rules of play as a result of selecting a certain business model. To support the argument, Casadesus-Masanell and Ricart (Casadesus-Masanell and Ricart 2010) employed case study research and compared the business model of two firms, TDC and Telmore. The paper has contributed to the discussion on business model by offering a simple integration of business model with strategy and tactics.

The last paper in this study was written by Johnson, Christensen and Kagerman (2008). The authors defined business model as four interconnected elements that help firms to create and deliver value. Those elements are customer value proposition, profit formula and resources and process. Customer value proposition is the key objective for any business. Successful business should start by identifying a clear value for their customers. In other words, products or services should perfectly fit with the needs of customers. TATA in India is the most famous case on how firms propose a new value especially for scooter family. At that time, the cheapest car in India cost around five times of the scooter's price. By offering an affordable and safer alternative for scooter family, TATA built a strong value proposition that convinced scooter family to buy the product. Similarly, a Liechtenstein-based manufacturer of tools for construction industry, Hilti, offered a rental system for tools. For their customer, owning tools may cost a lot of money. Hilti offers a new service by allowing contractors to hire the tools as well as manage customer's tool inventory. By providing the tools when the customers needed and promise that the customers always receive the best tools, Hilti created a strong and more powerful value proposition than their competitors. Moreover, this attractive business model should be followed with a proper profit formula. For Hilti, a lease or subscription model would be an ideal option. The customers pay a monthly fee but get access to wide range of tools including repair and maintenance. The next element in business model is to identify key resources and process. By definition key resources can be assets, human capital, knowledge or even intangible assets such as strong brands and solid distribution channels.

Table 7: Main findings

Authors	Findings
Teece (2010)	The author tried to provide clarity on the definition of business model. According to the paper, business model is simply a reflection of firms' assumption about what customers want how the firms can meet their needs and make profit.
Chesbrough and Rosenbloom (2002)	Using XEROX as a case study, the authors explored how business model capture value from the early stage of technology.
Chesbrough (2010)	The author employed an analysis on business model innovation by focusing more on understanding barriers. There are at least three components to deliver a good business model, namely experimentation, effectuation and leadership.
Zott, Amit and Massa (2011)	The authors performed a literature review on business model. They found that business, as a concept has developed separately where authors are not well connected in one common body of knowledge. However, there is a common understanding regarding how to capture and deliver value.
Casadesus-Masanell and Ricart (2010)	The authors developed a framework to differentiate business models from strategy and tactics. Business model is closer to an art than science. Therefore, the definition is still ill defined but it represents firms' strategy.
Johnson, Christensen and Kagerman (2008)	The authors provided definition of business model and decomposed business model into three elements, value proposition, profit formula and key resources and process.

3.4 Factors contributing to the successful economic performance and strategic impact of business model

Based on the literature review on business model, several factors can be considered in the context of developing successful AM business.

Imitability, scalability, and integrability

A good business model should be difficult to imitate. Firms should not rely on economic scale to prevent competitors to copy their business (Demil and Lecocq 2010). In fact, firms often assume that they build the business based on the uniqueness of their product, process or skill. It is important for any business model to reflect the ability scale up. That ability such as internal capacity, slack resources, human capital will enable a new business to adapt and manage the increased demand. When the demands change due to the successful implementation of business model, a good business model should allow firms to prepare for an expansion. Another critical element in business model is the ability of business model to integrate all elements into current and future business. To have a successful business, all elements in the business from suppliers to customers should be orchestrated to produce value to the whole value chain.

Capability to overcome firms' path dependence and the dominant logic

Firms that have been in business for several years have developed dominant logic regarding how the process and market should work. In 2005, Kim and Maurborgne introduced blue ocean strategy as a tool to think outside the box. Firms are encouraged to be creative and create their own market. It is suggested that firms stop to copy what their competitors are practising in the business. Instead, they need to develop a new way of doing business. For example, IKEA have revolutionised the furniture industry with the way how they package the product and how low price has become an attractive proposition for many buyers. Overcoming dominant logic is the biggest barrier for any firms to sustain their growth. KODAK went bankrupt because it was unable to break its industrial practices. The company had brought one of the first digital camera in 1975 but it failed to materialise the new technology as a part of their business (Gassmann, Frankerberger, Csik 2014). A similar story is experienced by the big companies in music industry (Warner, BMG, EMI) (Gassmann, Frankerberger, Csik 2014). Most of them failed to overcome their dominant logic. With the introduction of MP3 technology and internet technology, the entire music landscape has changed by the introduction of new companies such as Spotify. Streetline shows another example on how a firm develops stronger value proposition by overcoming dominant logic. They developed a technology to identify a free parking space. Using a low power but cost effective sensor, the data can be transmitted over the internet to appropriate applications. However, the company has an interesting way of delivering the value. Instead of selling to drivers as customers, streetline targets cities and municipalities as their customers. A city or municipality can earn an enormous income by creating an efficient way of managing parking system. In addition, the technology can also be used to prevent non-paying drivers (Gassmann, Frankerberger, Csik 2014).

Focus on business model rather than the product or technology

Firms that develop technology or innovative product often fail to target proper customers. A Segway company, for instances, has created one of the most interesting products in transportation. However, the company failed to capitalise and diffuse their technology. It is important for the business model to focus on value proposition and do not concentrate highly on the product development.

Failure to identify actors/stakeholders

A successful business model requires firms to understand all actors in the business ecosystem. The objective of any business is to fulfil customers' needs. As a result, customers should be the main focus for any business. However, firms should not limit their attention on the current customers that they are currently serving but also potential customers that are on the edge of their market. Firms should also recognise the role of business partners. This category includes suppliers, distributors, professional support firms, and other participants outside the business such as university's researchers, business consultant, and training providers. Lastly, successful business should learn from other firms whether they are directly or indirectly competitors.

Failure to consider influencing factors

While many businesses have been triggered as a result new technology, developing a new business model needs to consider potential risks and threats from technological advancement. Many successful businesses have failed because of lack of awareness of the potential technology substitution. As technology develops rapidly in an exponential way, building a business based on the latest mobile technology is likely to face a huge risk. XEROX has many failed business model although they have developed the most advanced technology in copy machine. Apparently, XEROX found a new business model where customers can hire the machine and only pay the maintenance fee. Using the new business model, XEROX's revenue has increased almost 20 times in 20 years (Chesbrough 2007; Chesbrough 2010). Another influencing factors that can be a threat for business is regulatory change and megatrend. Pharmaceutical firms rely on government's policy and regulation. A new trend in policy discourse may have a significant impact on business.

Capability to develop and strengthen new competencies

In designing a new business, firms requires new competencies such as creativity, insights into customer's need and capability to process information from suppliers and distributors. The fact that new technology offers a new way of delivering value, new routines need to be developed to match firms' value proposition. Business model should consider how firms will create, manage or gather new competencies and also how the changing business will influence the current competencies. As Teece (Teece 2010) mentioned that designing a business model is like arts in that many factors are involved and no result is guaranteed but the changes of getting a good result from business model is greater if firms have a deep understanding of their competencies.

To summarise the findings, we concluded that the factors that contribute to the success of AM businesses from business model perspectives can be categorised into two main factors.

a) Innovative elements of business model
b) Capability to implement business model from firm's perspective

With regard to the innovative elements of business model, the literature has been arguing the importance of business model to be distinctive and unique. By developing sets of skills and capability, business model may create barriers to be copied and replicated which at the same time allows firms to expand and grow their businesses. Factors such as the ability to identify the main actors and stakeholders is critical. Firms often focus on serving customers while the whole business ecosystem is bigger than just their customers. Creating value and delivering value for other actors in the supply chain needs to be considered as it plays a significant role to sustain the business. Business model also needs to recognise factors that may influence their business, such as technological threat, regulation and global trend. Fail to recognise those factors may cause the business to suffer.

Another factor that influences the success of the AM businesses is related to firms' internal capability to implement business models. The capability includes knowledge management, organisational and managerial structure, operational management and supply chain. In order to implement business model innovation, firms need to break from their dominant logic and path dependent while at the same time develop new competencies.

Table 8: Factors for successful AM Business

Innovative elements of business model	• Imitability, scalability, and integrability • Fail to understand the stakeholders • Fail to consider influencing factors
Capability to imple-ment business model from firm's perspective	• Capability to overcome firms' path dependence and the dominant logic • Focus on business model rather than the product or technology • Identifying and strengthening new competencies

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4 Economic performance and strategic impact at the project-level[7]

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4.1 Introduction and method

Additive manufacturing (AM) innovations are carried out in different projects where new technologies, products or services are created and delivered to customers. New product and service development and technology management are slightly different fields of research, and AM is a source of innovations on both fields. The success of an AM innovation project does not only deal with completing the solution on time, in budget, and according to customer specifications, but also with achieving the innovation acceptance on the market, among customers, and reaching business value for those who have created the innovation.

This review concentrates on the factors for AM innovation success in terms of economic performance and strategic impact at the level of AM-related innovation projects. The intent is to review and summarize current-state knowledge about the antecedents (i.e., factors) and indicators (i.e., measures) of impact (i.e., success) in AM innovation projects. It is clear that the project level is connected to the firm and business model (or network) levels, too, and sometimes it is difficult to distinguish between them, but this review is focused on projects, whether in or between firms.

The current understanding on project success follows a contingency view: different projects have different success factors (e.g. Shenhar and Dvir 2007). Shenhar and Dvir (Shenhar and Dvir 2007) particularly encourage to take into account the project's novelty, technology, complexity and pace, when defining management practices for the projects. Therefore, also in this review we acknowledge that there are different types of AM innovation projects in terms of these kinds of factors. Particularly, we differentiate between 1) technology development; 2) technology implementation and adoption; and 3) new product and service development, as different types of AM innovation projects, as summarized in Figure 12. It is possible that the literature review reveals some other project types for further analysis and comparison, but this simple division is used as a starting point to categorize previous research.

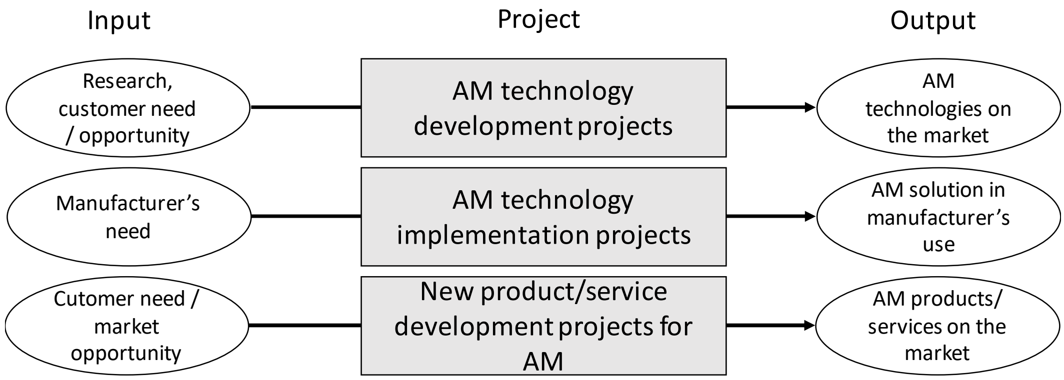

Figure 12: Overview to different kinds of projects concerning AM innovations.

For the purposes of this review, we sought for previous research literature with two complementary search strategies. First, we did a **systematic search** in the Web of Science, using "acceptance" or "adopt*" and "additive manufacturing" as the search words. We reviewed the titles and abstracts of the articles and retained such articles that appeared as relevant to the task, resulting in a total of 39 relevant articles. After this initial search, we reviewed the abstracts of the articles and consequently

[7] No one else but the chapter authors can be held responsible for the contents in their chapter

removed some articles from further exploration. For example, purely technical and conceptual papers and such papers where impacts/acceptance was not covered at the project level were excluded. Second, we did a **purposive search**, to find other relevant project-level studies both by identifying relevant authors during the first phase and continuing with a snowball approach from the article reference lists, to add further possible articles and thereby enrich understanding of specific project types. As a result of these two phases, we chose to include 21 articles for a more detailed analysis. We will use some additional articles (particularly conceptual papers) where appropriate to develop and support the main argumentation. It is clear that this review is limited through the use of the search words, and other research may exist with a more versatile search terms.

With the articles, we proceeded to analyse the contents in a systematic way. Conceptual studies were treated primarily as sources to describe the covered project types and in the discussion part, whereas 21 empirical articles were analysed with further detail. We divided the included empirical studies according to project type to three categories, in line with Figure 12. We identified the typical characteristics of the projects included, as well as possible exceptions. We then mapped the articles in terms of their empirical context (including the product or technology and industrial field) and method, the way in which impact and / or acceptance was studied, and the possible antecedents of impacts. This analysis is reported in summary tables by project type. In each project type, we also sought for the commonalities and differences across the included studies, both to highlight the key learnings and to point out gaps and prospective avenues for further research. With the findings, we clustered both the impact measures and their antecedent factors, to create an overview of the logic with which market and strategic impact are achieved from AM innovations at the project level. This is presented as the main result – a conceptual framework.

In the following chapter, the results are reported by project type, according to Figure 12, and impacts and their antecedents are categorized and summarized in a framework picture (Figure 13) to illustrate the performance logic of AM innovations at the project level. In the end, the findings are discussed generally, and domains for further research are proposed.

4.2 Results

4.2.1 Projects for developing AM technologies

Some studies focus on some aspects of developing AM-related technologies: software solutions, data models, material use, and the specific AM-technology. For technology development projects, novelty and uncertainty are typically high, whereas the complexity and technical advancement may vary across projects. These projects may be highly technical and, thereby, many technically-oriented papers were purposely excluded from further analysis, as they did not really cover market or strategic impacts in any way. Often, their primary orientation was to demonstrate the functionality of the focal technology only.

Table 1 summarizes some studies that reveal potential impacts, in terms of accepting the technology (Ding et al. 2018), taking integrated models to use in the value chain (Bonnard et al. 2018), and optimizing material consumption (Jin et al. 2017a, 2017b). These studies typically focus on a specific case example and use experimental or modelling approaches, as the research design. While these studies do not purposely cover the antecedents of impacts (the right-most column in the table), we have interpreted the variables included in the experimental designs as such antecedents.

Table 9: Summary of studies concerning the projects for developing AM technologies.

Reference	Approach	Context and method	Measure of impact	Antecedents of impacts
Bonnard et al. 2018	Proposes a new data model for AM, to advance the digital AM chain	Building on STEP-NC data for AM, using a hierarchical object-oriented model. Modelling and experiments with two test parts.	Integrated data model throughout the AM value chain.	Product structure; technology and tools; processes and strategy.
Ding et al. 2018	Identifies requirements and develops a software solution for the process planning of a selected AM technology	Laser wire-feed metal additive manufacturing. Experiments and design work.	Acceptance of the AM technology	Identification of key issues in the process; technical solutions; control; flexibility.
Jin et al. 2017a	Proposes a methodology for generating the deposition path for extrusion-based AM of thin-walled parts	Extrusion-based layered deposition. Demonstration through two thin-walled test parts.	Optimized material consumption, build time	Path patterns and designs
Jin et al. 2017b	Proposes a design strategy that optimizes material consumption for large-volume solid parts.	Design research. Demonstration through two case examples.	Minimized material consumption. (Thereby, environmentally friendly manufacturing, and broader AM diffusion)	Part internal optimization, process planning, implementation with sliced data, path planning

4.2.2 Projects for implementing AM technologies

The majority of the analysed research focused on projects that dealt with implementing certain AM technologies. For technology implementation projects, the degree of novelty and uncertainty are low to moderate, and again the level of complexity and technical advancement may vary across projects. Here, it was particularly difficult to differentiate between the project and the firm as the level of analysis, as it is often a certain firm implementing the AM technology in a project. The focus in these studies typically was on a certain AM technology and its implementation in a certain context or situation. To offer a more fine-grained picture of the ongoing research, we identified three types of main impacts, covered in previous literature and summarized in Table 9.

1) Some studies focused on AM **technology adoption or diffusion generally**. Research has attempted to identify general barriers and drivers for adopting AM technologies in certain conditions/environments (Dwivedi et al. 2017; Martinsuo & Luomaranta 2018; Mellor et al. 2014), explored and experimented with the decision to adopt AM technology (Baumers et al. 2017; Steenhuis & Pretorius 2016),

and compared alternative processes to justify the development and diffusion of AM technology (Baumers et al. 2016). Table 2 introduces a variety of antecedents for the adoption of AM technology, revealing that some studies take a strong cost emphasis as an antecedent of AM adoption whereas others rely on a more holistic view, such as the framework of Mellor et al. (figure 13).

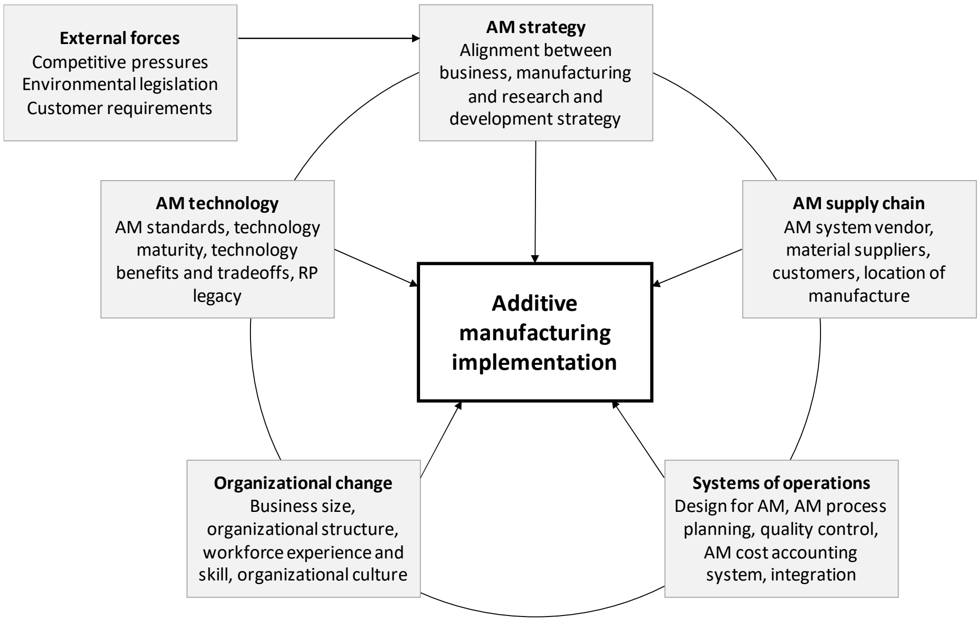

Figure 13: Overview to key factors in AM implementation (Mellor et al. 2014).

2) A group of studies dealt with AM technology adoption and how it **impacts in the firm's production system**. The interest in these studies is to inspect and determine whether AM is a desirable production strategy and how it compares with conventional production (Achillas et al. 2015; 2017). One study has focused on environmental impact of using AM (Le Bourhis et al. 2013), and environmental issues have been covered in some more technical papers, too. These studies concentrate on such antecedents that are primarily easy to measure – cost, time, and energy or material consumption – but also some qualitative measures are suggested, as shown in the right column of Table 10.

3) There are also such studies that concentrate on how AM technology adoption **impacts in the broader supply chain.** Such studies discuss the consequences of adopting AM technologies, particularly in terms of supply chain performance such as inventory turnover or customer satisfaction (Ghadge et al. 2018; Li et al., 2017; Muir & Haddud 2017), or changes in the supply chain structures and processes (Durach et al. 2017). The antecedents are similar to those mentioned previously, and include both barriers and drivers, and measurable and qualitative antecedents.

Table 10: Summary of studies concerning the projects for implementing AM technologies.

Reference	Approach	Context and method	Measure of impact	Antecedents of impacts
Technology adoption or diffusion				
Baumers et al. 2016	Comparison of cost performance in alternative production processes	Electron beam melting and direct metal laser sintering compared, five test parts. Experiment.	Development, diffusion and societal impact of AM technology.	*Measurable:* cost structure, including build time, energy consumption, labor and overhead costs, machine costs
Baumers et al. 2017	Activity based costing method, to guide AM technology adoption decision based on real parameters in production.	Components for food packaging machines. Experiment.	AM technology adoption decision, particularly based on total production cost (savings compared to traditional manuf.).	*Measurable*: capacity utilization (time, material, component lifetime), ancillary process steps, the effect of build failure and design adaptation; saving of energy
Dwivedi et al., 2017	Barriers to implementing AM	Automotive sector in India. Panel study with industry experts in two car manufacturing firms.	Implementation of AM technology (from the perspective of low implementation rates)	*Barriers*: technological limitations, high costs, unavailability of skilled operators, designers' attitude, workers' resistance, management support; information asymmetry, vendor trust, IPR threats , government support
Martinsuo & Luomaranta 2018	Challenges and solutions for adopting AM in SMEs	Exploratory study with SMEs in mechanical and process industries, metallic AM	Adoption of AM	Technology-related, strategy-related, supply chain related, operational, organizational and external factors as barriers (or drivers), following Mellor et al. 2014
Mellor et al. 2014	Framework of factors relevant to AM implementation	Qualitative case study with a supplier of AM products for various industries.	Adoption of AM	Technology-related, strategy-related, supply chain related, operational, organizational and external factors
Stenhuis & Pretorius 2016	Adopting 3D prenting by consumers	Exploratory multi-method study, covering both technology adoption and competitiveness of AM products	Consumer adoption Purchase decision Satisfaction with purchase decision	Information availability, familiarity, intended frequency of use, user-friendliness, support

			Recommendation to others	
Impacts in the production system				
Achillas et al. 2015	A methodological framework to determine the optimal production strategy (AM and others).	Security keyboard polymer housings. Single case, framework combining multi-criteria decision aid and data envelopment analysis.	Optimal production strategy: selecting the right strategy among alternative technologies	*Measurable*: Cost, lead time (that vary by production volume) *Qualitative*: Quality, customization, flexibility, defect rate, material availability, geometrical complexity, capital requirement
Achillas et al. 2017	Comparison of alternative production strategies (AM vs. traditional).	Electronics manufacturing. Single embedded case, four product categories in one firm.	Optimal production strategy: selecting the right strategy among alternative technologies	*Measurable*: Lead time and total production cost
Le Bourhis et al. 2013	Methodology to evaluate and model the environmental impact of AM	Comparison of machines. Modeling.	Environmental impact	Electricity consumption Material consumption Fluids consumption Manufacturing time
Impacts in the supply chain				
Durach et al. 2017	Barriers to adopting AM technologies, and anticipation of supply chain impacts of AM.	Industry and academia. Panel study with 16 experts at the intersection of AM and supply chain management.	Supply chain implications: structure, logistics, customer centricity, capabilities	*Qualitative.* Emerging manufacturing processes and their features. *Barriers*: costs, technical limitations, geographic, labor-related.
Ghadge et al. 2018	Impact of AM implementation on spare parts inventory and supply chain performance	Aircraft spare parts supply chains. Case study, modelling, simulation.	Supply chain performance / efficiency (inventory level; service level)	Costs, lead times, demand, safety stock, orders, back-orders, production time Required service level Uncertainties
Li et al. 2017	Effects of utilizing AM to produce spare parts within the structure of a spare parts supply chain	Systems dynamics simulation in spare parts supply chains (one supplier, one manufacturer)	Supply chain performance: Cost Carbon emission	Demand; use; inventory; production time; transport time; delays; AM production rate
Muir & Haddud 2017	Impact of AM on supply chain performance in spare parts supply chains	Questionnaire survey in machinery and instrument manufacturing industries	Inventory performance Customer satisfaction	Customer sensitivity to price, delivery lead time and supply risk

4.2.3 Projects for developing and launching new AM products and services

One of the key drivers for implementing AM has been the possibility to design and implement completely new kinds of products. Also, AM enables the offering of new kinds of services as part of the manufacturing supply chain. The projects for new AM product and service development may vary significantly in terms of complexity, novelty, uncertainty and technical advancement, as well as contextual issues. The business aspects of AM-related new product and service development projects have not been studied broadly at the level of the project, and the extant research is still somewhat technology-centric. It is possible that the experimental phase of AM technologies implies merely small market trials for AM-related products and services and, thereby, little research in the actual market success. Also, it is apparent that there is research that tackles the issue, but typically at the level of the firm (without specifying the project).

Table 11 summarizes some studies, primarily concerning selected products (Baumers et al. 2016b), their business case (Knofius et al. 2016), use of AM during new product launch (Khajavi et al. 2015) and novel e-commerce channels (Eyers & Potter 2015). These studies have very versatile ideas of the success and impact of AM innovations, ranging from energy consumption, material flow improvement and production performance to value of investments and making the right business decisions. Also, the antecedents of impacts are very varied, as shown in the right-most column of table 11.

Table 11: Summary of studies concerning projects dealing with AM product and service development projects.

Reference	Approach	Context and method	Measure of impact	Antecedents of impacts
Baumers et al. 2016b (JIE)	Assessment of energy consumption in producing complex product shapes.	Manufacture of a titanium test part, using electron beam melting. Experimental.	Process energy consumption	Variation of product shape complexity and cross-sectional area
Eyers & Potter 2015	Identifying e-commerce channel designs in AM supply chains	Case examples in different industries for four alternative e-commerce channel designs.	Improvements in material flow and information flow. Manufacturing profitability and service levels. Market visibility; customer relationship; future business	E-commerce channel design: tele-manufacturing, collaborative manufacturing, local manufacturing, user manufacturing
Khajavi et al. 2015	Use of AM combined with conventional production methods (i.e. hybrid methods) during early manufacturing in new product launch	Incremental sheet forming, 12 cases. Scenario modeling.	Net present value of investment (Flexibility to market feedback Time to market)	Demand forecast Costs Timing of the switch between AM to conventional production
Knofius et al. 2016	Identification of economically valuable and technologically feasible business cases for AM in spare parts logistics	Part supplier in the aviation industry. Analytic hierarchy process – ranking of components appropriate for AM.	Improvement potential in production performance Choosing the right spare parts business cases for AM Adoption of AM in after sales supply chains (spare parts)	Demand rate; resupply lead time; agreed response time; remaining usage period; costs of manufacturing and safety stock; num-

Reference	Approach	Context and method	Measure of impact	Antecedents of impacts
				ber of supply options; supply risk (Weighted)

4.3 Summary of impacts and their antecedent factors

Based on the above analysis, we further grouped all the impact measures covered in previous research (in the tables, column "measure of impact") into six categories that appeared to repeat across the reviewed studies. A lot of research focuses merely on the **adoption and acceptance of AM technology**, which can be considered as a predecessor of actual market and strategic impacts. Similarly, some studies concentrate on **selecting the optimal strategy and business case for AM,** also as an antecedent of actual impacts. These two categories were dominantly present in the research concerning AM technology implementation projects and they deal clearly with getting the technology into business use, which is necessary before further business impacts. Four additional broad categories of market and strategic impact were revealed at the project level: **manufacturing performance improvement**, **supply chain performance improvement**, **customer satisfaction** (including purchase decisions and recommendations), and **environmental impact**.

Similarly, we grouped the antecedent factors of those impacts into five broad categories: demand, innovation characteristics, process characteristics, resources, and external. Of these, process characteristics dominate in previous research, and also innovation characteristics are covered fairly broadly.

- **Demand** factors deal with demand and orders, demand forecasts, customers' familiarity with the offerings and intended use and sensitivity to price as well as expected service levels.
- **Innovation characteristics** deal with the technological features and solutions for AM, complexity, cost structure and implementation of AM in products, as well as the customization, variation, user friendliness and other properties of AM technologies and products. Also technical limitations may appear as barriers.
- **Process characteristics** deal with time and costs required in AM processes, including material and energy consumption, lead times, and requirement of labour, transport and overhead. These issues are covered in previous research in various ways, both as barriers and success factors. Also flexibility, information availability, planning, and general issues regarding processes and strategy are included.
- **Resources** are covered in previous research primarily as a barrier to advancement, in terms of workers' resistance and attitudes, and unavailability of competent labour.
- **External factors** appeared also primarily as barriers and threats, particularly concerning ownership of IPR, supply risks, lack of government support, and geographic issues.

Figure 14 summarizes the key factors and impact indicators found through the literature review concerning AM innovations at the project level. Although the literature itself does not explicitly discuss the project type (in terms of e.g. novelty, uncertainty, complexity, technical advancement, contextual factors etc.), this review has covered three types of projects and points out the need to include project type and contextual factors as relevant control factors, when the framework is developed further. The need to acknowledge the different degrees of innovation (incremental … radical) in AM implementations has also been acknowledged in some conceptual research (e.g. Steenhuis & Pretorius 2017)

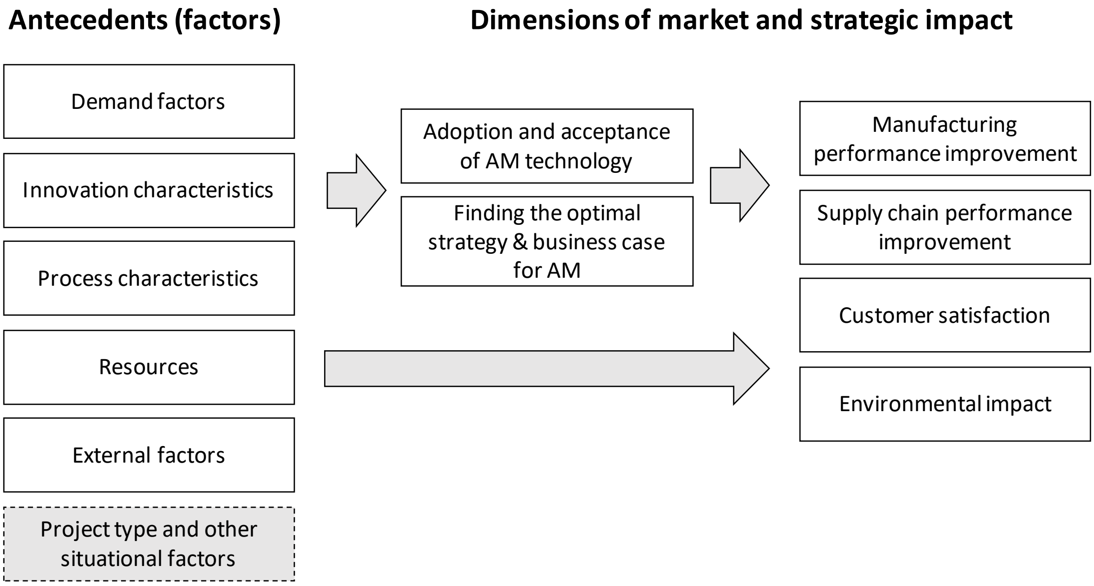

Figure 14: Summary of key factors and impact indicators for AM innovations at the project level.

4.4 Discussion

This review has focused on market and strategic impacts reached through different types of AM-related projects, and their possible antecedent factors. As AM innovation projects differ in their radicalness (Steenhuis & Pretorius 2017), we also acknowledged different types of projects and covered both AM technology development and implementation projects, and new AM product development projects. The majority of relevant research has taken place in connection with AM technology implementation projects where certain technologies are adopted and experimented with. The review revealed a variety of impact indicators and antecedent factors, summarized as a conceptual framework in figure 13.

The early phase of development concerning AM technologies was reflected in the limited number of business-oriented studies and the prevalence of such impact indicators as adoption and acceptance of AM technology and choice of strategy and business case for AM. As these indicators primarily relate to the implementing the AM technology for a specific need, they do not, yet, suffice as core indicators of market and strategic impact. In the analysis summary, we took these indicators only as intermediary indicators, preceding actual improvements achieved in manufacturing performance, supply chain performance, customer experiences and environmental matters. The project-level research does not cover such issues as market position or reach, achieved revenues and business value, or return on investment, which may be discovered in firm-level studies. The review showed that single studies are often concerned with a specific performance indicator only, and a holistic view of project level issues in AM innovation has not been utilized in research, so far.

AM innovation projects need to take into account various antecedent factors, to achieve market and strategic impacts. Previous research has covered the factors both from the perspective of barriers and requirements, and both in terms of measurable and qualitative variables. While the overall framework of Mellor et al. (Mellor et al. 2014) reveals thematic categories of issues that have to be taken into account in implementing AM technologies generally, our review was focused on factors required for specific AM innovation projects to reach business impacts. Demand, innovation characteristics, process characteristics, resources and external factors were explicated as the main categories, each including more detailed factors. While many of the measurable variables deal with energy and material consumption, various types of costs, and lead times, the previous research reveals that

AM innovation performance is a complicated phenomenon, requiring also difficult-to-measure qualitative factors and a skilled combination of antecedent factors relevant to the specific type of innovation. The analysis namely suggests that it is necessary to take the innovation project type and context into account, when examining the connections between antecedent factors and impacts. Although it is impossible to differentiate the factors between project types or business contexts through the inductively coded data from 21 reviewed articles only, we follow the contingency view in suggesting the alignment of factors and impacts according to the innovation type and context.

The tentative findings of this review open up some possibilities for further research. In particular, we propose the following avenues for empirical research:

- In-depth case studies on specific AM innovation project types, to discover the centrality of specific antecedent factors for each project type (and specific contexts).
- In-depth case studies on early adopters of AM, to clarify the path from AM adoption and business case selection to the different dimensions of market and strategic impact.
- Comparative studies across different AM innovation project types, to understand how the conceptual framework varies across project types and contexts.
- Developing the conceptual framework into a project-level model, to be tested in hypothetic-deductive studies including all kinds of AM innovation projects.
- Further research to categorize and prioritize the qualitative antecedent factors within and across AM innovation project types (possibly by comparing across projects differing in their impacts).
- Exploratory and in-depth studies about AM-related service offerings, their development, and market and strategic impacts.

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5 Factors for AM Social performance[8]

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Tecnalia

5.1 RRI management

5.1.1 Definition of terms: RRI, CSR & ELSA

In this section we define the RRI theoretical framework that allows a coherent and logical identification and of RRI openings in the AM value chain. To start with, Responsible Research and Innovation is an evolving concept and there is no fixed definition or protocol to be followed in order to be "responsible." In a business context, RRI, as well as Corporate Social Responsibility (CSR), refer to "the responsibility of enterprises for their impacts on society"(European Parliament 2011). The main difference between both is that CSR is a management model aiming at generating social impact beyond business profit, while RRI is focused on the opening up the process of production and use of scientific and technological knowledge to society. Research on ethical, legal and social aspects (ELSA) of new technologies and scientific developments is also concerned with impacts and consequences, but it's an external and theoretical approach that doesn't aim at larger involvement of stakeholders, transparency and dialogue in the way that RRI does. This is the "process dimension" of RRI, in other words the rise of "public" in the R&D process that builds citizens empowerment and public acceptance of innovation through science communication, education and engagement. The process dimension addresses the moral responsibility of governments and business to create democratic scientific processes and allow citizens exorcise their rights by having a genuine vote.

5.1.2 Social impact

The outcome dimension of RRI is concerned with achieving the "right" social and environmental impact, where however social impact is still "jargon – broad, vague, and somewhat inaccessible by definition" (Woodson 2013) as defined by some authors. Therefore, a major step in this analysis is the development of a useful conceptual definition social impact. There are some core principles that can be articulated and thus social impact can be:

1) Direct or indirect
2) Short, mid- and long term
3) Real or perceived
4) Affecting "individuals, families, groups, societies, countries, and even the global community" (Barrow 2008) and thus altering social structures, behaviour, relations, interactions, and cultural features such as beliefs, norms, and values
5) Positive, known as "societal benefits", negative, known as "social cost" or speculative or "unknown effects/impacts"

Thus social impact can be described as the consequences on "human population of any action that alters how people live, think, behave, and react to each other" (Burdge 2004).

In this more concrete framework it becomes evident that social impact should be strictly differentiated from environmental impact and or economic impact, can be intentional or unintentional and could provoke long-term unknown effects on society and its structures, attitudes and values. As environmental impact is already addressed in the management of the involved AM companies and economic

[8] No one else but the chapter authors can be held responsible for the contents in their chapter

impact is a topic of a different section, in this part we focus on Social impact which is also the main area of RRI.

After these specifications it remains questionable if some of the most discussed topics in AM like Intellectual Property, Safety and Security, Product Liability, Insurance, and Political change (when one country's unique manufacturing sector is undermined, or when western countries regain their manufacturing power from low-cost subtractive manufacturing regions) (Mayer-Brown 2013) fall within the category of social impact. Although that these issues affect society in one way or another, they still don't alter individuals´ or social beliefs, perceptions, structures or attitudes and thus could be discarded as social issues within the scope of this research. In contrast, the possibility of some additive manufacturing techniques to fabricate organized tissue constructs for repairing or replacing damaged or diseased human tissues and organs (Melchels et al. 2012) is a redefinition of the human from being a creation to being a co-creator.

According to some authors this can lead to deterministic interpretation of human destiny and reduction of humanity and human biology to their genetic substratum (Peters 1997). The guiding question here is "*Where will we end up*?". The power of the new human opens a future of potential for them not only in terms of biological survival but also a creative sphere as shown in the poem "I AM A MAKER" of Malcolm S. Hoover 2014 (Deloitte 2013).

The AM has the potential to change our way of working, purchasing and learning as greater portion of the research and innovation value creation will reside more and more in the customization/personalization component (European Parliament 2011). People will combine and recombine, both in urban areas and in virtual communities, "as necessary to exchange skills, capital or learning, creating a resilient and agile network structure that supports the decentralization of some activities" (Deloitte 2013).

5.1.3 Anticipation, precaution and regulation

The first part of our research problem thus is to anticipate the social impact resulting from AM, at all levels of product & service development and in both sectors we are focusing on, namely automotive and medical appliances. Here we take advantage of the precautionary principle of RRI, searching for a healthy balance between precaution and innovation. As some actors advocate to "give innovators a bit more breathing room" or, "don't rush to regulate", we should keep in mind the possible social cost of under-regulation as well as the possible cost of over-regulation of different aspects of AM. When future social risks are detected we need to deal with them and be able to answer the "if to regulate", "when to regulate" and "how to regulate" questions (Eggers et al. 2018).

Source: Deloitte centre for Government (2018)

Figure 15: Principles for the future of regulation

The precautionary principle is an integral part of RRI, however there are different understandings of its purpose and application, mainly defined by the key variable "degree of scientific uncertainty". According to the EC "*whether or not to invoke the precautionary principle is a decision exercised where scientific information is insufficient, inconclusive, or uncertain and where there are indications that the possible effects on the environment, or human, animal or plant health may be potentially dangerous and inconsistent with the chosen level of protection"* (European Commission 2000). The "if to regulate" question is a key decision, keeping in mind that too much precaution can hamper the technological progress and the economy, leading to a large number of regulatory false positives and unnecessary over-regulation (European Parliament/Bourguignon 2015).

However, while risk assessment is a fundamental part of business management and aims to improve quality and maximize benefits, precaution is the avoidance of risks that are difficult to identify and evaluate. And to make even more complex, these risks may not even be real and can "only be avoided by refusing to improve quality, be it product quality or the quality of life" (Apel 2002).

The guiding idea is that decisions and developments in science and technology should be based first on human and societal values and only secondarily on scientific and technological needs. Thus, we face a key research challenge: How to best protect citizens, avoid unnecessary regulations, and allow AM technologies and businesses to flourish? The most transparent and democratic way to address it is the collaborative regulation, which goes in the same line as RRI and offers a number of benefits for the social as well as for the economic stakeholders. According to the EC, RRI is "the comprehensive approach of proceeding in research and innovation in ways that allow all stakeholders that are involved in the processes of research and innovation at an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of options open to them and (B) to effectively evaluate both outcomes and options in terms of societal needs and moral values and (C) to use these considerations (under A and B) as functional requirements for design and development of new research, products and services" (European Commission 2013). In other words, RRI implies that research and innovation process is conducted in a transparent, inclusive and responsive way.

The involvement of society and different stakeholders into the R&D processes of AM should aim at avoiding social costs and maximizing social benefits through the creation and promotion of RRI standards. Similarly to CSR, RRI cannot be certified but could follow the example of ISO 26000 on Social

Responsibility and develop standards and guidelines for businesses and research institutions that need to structure their research and innovation processes in a RRI-compliant way. After five years of negotiations between industry, consumer groups, government, and NGOs from around the world, ISO 26000 was launched in 2016 (ISO 26000:2010). It aims at all types of organizations independently from research area, location or size and makes clear to them what social responsibility is, facilitating in this way the adoption of best practices and more adequate RRI governance structures (Deloitte 2013).

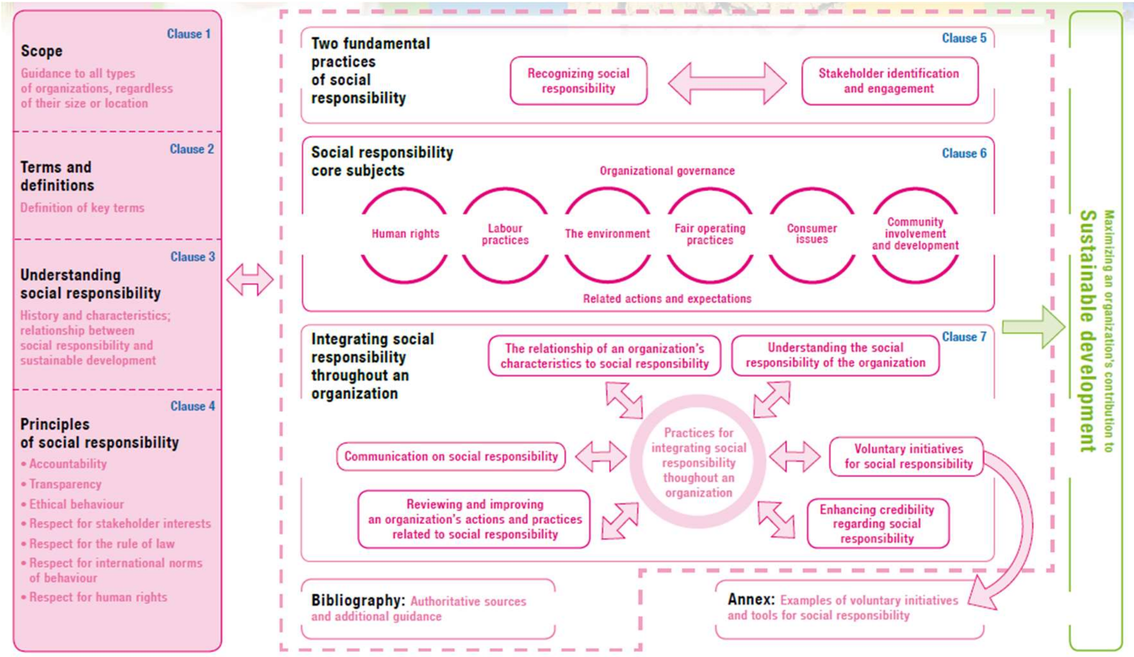

Figure 16: ISO 26000 - Social responsibility

In this research we aim at creating comprehensive and applicable RRI standards targeting exclusively the AM sector. The guideline will encourage companies to go beyond legal compliance, to build an understanding of RRI and its principles and also to alert them to problem areas or blind spots previously neglected in their management and planning. It will provide them with a set of participatory tools that could open their R&D processes and create more transparency and inclusiveness. The guide will provide orientation towards the five areas of RRI, namely gender equality, open access, public engagement, science education and governance together with some specific assessment indicator for each area. Furthermore it will provide useful information on trends, principles and practices related to citizen empowerment and citizen science in the AM industry. The RRI guideline/standard will be useful not only for AM businesses and research centers but also for public authorities and RFO that can use it to assess if the research is RRI compliant, in which areas and to what extent. In this way they improve their accountability and legitimacy and ensure that their funding is spent in a more responsible way.

In a nutshell, in the current research we establish a framework for RRI management consisting of the following steps:

- Identification of social Impacts and RRI openings within the innovation AM value chain
- Assessment of indicators for social impacts of AM
- Joint design of possible precaution measures or recommendations for regulation in order to avoid social costs
- Joint design of Standards on RRI in AM that can be adopted voluntarily by AM companies

5.2 References on RRI Indicators

The first initiative to collect RRI indicators took place in 2014 when the EC appointed a group of experts with the aim to define indicators for monitoring the impact of RRI. The report was published in June 2015 and provided a set of 100 qualitative and quantitative indicators called "Indicators for promoting and monitoring Responsible Research and Innovation" (European Commission 2015). The report had the ambition to identify and classify indicators that can measure impacts of 'RRI initiatives', 'RRI actions' and 'RRI activities' in the six of the RRI key areas: public engagement , gender equality, science education, open access, ethics and governance. It furthermore recommended the including of two additional aspects – sustainability and social justice/inclusion. One of the important conclusions of the report was that RRI is a dynamic concept and indicators for RRI can also be found beyond these six categories. The expert group defined that "responsibility in RRI is a matter of outcomes as well as characteristics of the processes that lead to the outcomes" (European Commission 2015), and considered three main dimensions: process, outcomes, and perception.

The greatest advance in the area of RRI indicators was made within the MoRRI Research, launched in 2013 as part of the European Commission's service contract RTD-B6-PP-00964 "Monitoring the evolution and benefits of responsible research and innovation" (MoRRI 2018). The MoRRI project (2014-2018) conceptualised and implemented the first RRI monitoring system in Europe. The result of the project were 36 "MoRRI Indicators" that became available in February 2018 and that provided detailed descriptions of each indicator in a tailored indicator fiche. The fiches are divided into three blocks of information: indicator characteristics, data collection specifications and assessment on availability of data, statistical robustnes and feasibility/replicability.

The "SUPER_MoRRI" project started in 2018 with the aim to ensure "sustained data collection, curation, further assessment and refinement of the MoRRI indicators" (Aarhus BSS Communication 2018). SUPER MoRRI has furthermore the ambition to "go well beyond the technical efforts of MoRRI" and develop a more scientific understanding of the RRI policy and practices and the different benefits they provide (Aarhus BSS Communication 2018). The MoRRI indicators for RRI are included in table 12.

Table 12: RRI Indicators (MoRRI 2018)

Public engagement categorisations
PE5 Public engagement performance mechanisms at the level of research institutions
PE6 Dedicated resources for PE
Science literacy and scientific education categorisations
SLSE2 RRI related training
Gender equality categorisations
GE1 Share of RPOs with gender equality plans
GE5 Share of RPOs with policies to promote gender in research content
GE8 Share of female heads of RPOs
GE9 Share of gender-balanced recruitment committees at RPOs
Ethics categorisations
E1 Ethics at the level of Universities
Open access categorisations
OA6 RPO support structures for researchers as regards incentives and barriers for data sharing
Governance categorisations
GOV2 Existence of formal governance structures for RRI within RF and RP organisations

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6 Conclusion

The author who conducted the fourth literature review (chapter 4) did not find general factors that affect social impact in the segment of automotive and medical application. However, the MoRRI report (MoRRI 2018) gave an extensive list of RRI indicators. Summarising it can be said that this literature review D2.1 revealed indicators and factors for market and strategic impact at three levels, which are (inter)organisational, business model and project level and it presents indicators for RRI.

Both the literature review focusing on the factors for market and strategic impact at the business model level (chapter 2) and literature review on factors for social impact gave significantly less factors than the other literature reviews. This can be explained by different level of knowledge and research work in the targeted levels of that literature review.

7 Summary of indicators

Four literature reviews were conducted that focused on three levels of analysis and three conceptualizations of performance indicators. To arrive at one coherent list of factors, the list of factors found in study 1 of this deliverable was discussed with work package 6 and it was analysed to what extent the foresight factors were overlapping with the factors found in study 1 or had to be considered as new factors or even categories. This resulted in a new, more complete, list of factors. For example, the category of megatrends was incorporated in the list of factors.

Then, the resulting list of factors was discussed with each of the authors of this deliverable. This resulted in 11 categories of factors for market and strategic performance at the three levels under study (see tables 13-21);

A. Innovator characteristics (demand side),

B. Innovation characteristics (which concerns the innovation itself),

C. Process characteristics,

D. Technological environment (physical),

E. Innovator characteristics (supply-side),

F. Innovation support strategy,

G. Other stakeholders,

H. Market mechanisms,

I. Values and Norms,

J. Megatrends.

Finally, in figure 17 a complete overview of all the categories and factors found is presented.

Table 13: factors belonging to the category 'A. Innovator characteristics (demand side)'

A. Innovator characteristics (demand side)
Customer level of education
Customer resources
Customer ned (necessity to buy)
Resistance to change
back-orders
Barrier: vendor trust
Customer sensitivity to price
demand (forecast, rate)
familiarity
intended frequency of use
orders
Required service level
use

Table 14: factors belonging to the category: 'B. Innovation characteristics'

B. Innovation characteristics
Relative technological performance
Compatibility
Compatibility (norms and values)
Flexibility
Radicalness of innovation
Perceived risk
Communicability
Relative price / cost / effort
Complexity
Reliability
Barrier: technical limitations
capital requirement
cost structure
customization
defect rate
geometrical complexity
implementation with sliced data
inventory
material availability
Part internal optimization
Path patterns and designs
path planning
Product structure
Quality
safety stock
technical solutions
technology and tools
the effect of build failure and design adaptation
user-friendliness
Variation of product shape complexity and cross-sectional area
adaptability to new concept of RRI value
replicability
integrability

imitability
scalability

Table 15: factors belonging to the category: 'C. Process characteristics'

C. Process characteristics
agreed response time
AM production rate
ancillary process steps
Barrier: costs (of e.g. manufacturing and safety stock)
Barrier: information asymmetry
build time
capacity utilization (time, material, component lifetime)
control
costs of manufacturing and safety stock
delays
delivery lead time
Electricity consumption
Emerging manufacturing processes and their features.
energy consumption
flexibility
Fluids consumption
Identification of key issues in the process
Information availability
labor and overhead costs
Lead time (that vary by production volume)
machine costs
Manufacturing time
Material consumption
process planning
processes and strategy.
production time
remaining usage period
saving of energy
stock resupply lead time
Timing of the switch between AM to conventional production
total production cost
transport time
Uncertainties

Table 16: factors belonging to the category: 'D. Technological environment (physical)'

D. Technological environment (physical)
Availability of industrialised production
Complementary goods and services
Enabling infrastructure
Materials supply
Barrier: IPR threats

Table 17: factors belonging to the category: 'E. Innovator characteristics (supply-side)'

E. Innovator characteristics (supply-side)
Financial strength
Brand reputation and credibility
Operational Supremacy
Learning orientation
Network formation and coordination
Barrier: designers' attitude
Barrier: workers' resistance
Barrier: unavailability of skilled operators
Barrier: labor-related.
Supply risk (normal and weighted)
E-commerce channel design: tele-manufacturing, collaborative manufacturing, local manufacturing, user manufacturing
number of supply options
organizational capacity

Table 18: factors belonging to the category: 'F. Innovation support strategy'

F. Innovation support strategy
Pricing strategy
Appropriability strategy (IPR)
Timing of entry
Marketing communications (including Strategic market development, sense of mission, Lobbying activities)
Pre-emption of scarce assets
Distribution strategy
Commitment (supply side innovator)
Network formation and coordination strategy
Barrier: management support;
support

Table 19: factors belonging to the category: 'G. Other stakeholders'

G. Other stakeholders
Current customer installed base
Previous customer installed base
Big Fish
Regulator (government, Lobbying activities, other)
Regulatory backlog
Liability for 3D printed components
project quality assurance
Judiciary
Suppliers
Effectiveness of the development process
Market Potential (sum of all potential customers)
Demand for specific applications in high price segments
insurance companies
Barrier: low government support
Barrier: geographic

Table 20: factors belonging to the category: 'G. Market mechanisms'

H. Market mechanisms
Bandwagon effect
Network effects and externalities
Number of options available
Uncertainty in the market
Rate of change
Switching costs
Availability of rules and standards
unforeseen (micro) events (including e.g. International political conflicts)
customer adoption process
Effects on other global supply chain
supporting political, regulatory, and market context
synchronizing economics, social and environmental objectives

Table 21: factors belonging to the category: 'I. Values and Norms'

I. Values and Norms
Environmental sustainability
Data privacy and security
Health
Justice
Control
Inclusiveness
Compatibility to cultural norms and values
Trust, benefits for society and potential threats
Responsibility and liability

Table 22: factors belonging to the category: 'J. Megatrends'

J. Megatrends
Increasing demographic imbalances
Diversification of education and learning
Shifting health challenges
Changing nature of work
Growing consumerism
Continuing urbanisation
Accelerating technological change and hyper-connectivity
Digital Transformation
Expanding influence of east and south
Globalisation
Climate change and environmental degradation
Aggravating resource scarcity
Increasing influence of new governing systems
Changing security paradigm
Increasing significance of migration
Role of governments
Diversifying Inequalities
Availability of energy
Ecological thinking
Potentially less pollution
Less usage of resources

Factors

A. Innovator characteristics (demand side)
Customer level of education
Customer resources
Customer ned (necessity to buy)
Resistance to change
back-orders
Barrier: vendor trust
Customer sensitivity to price
demand (forecast, rate)
familiarity
intended frequency of use
orders
Required service level
use

B. Innovation characteristics innovation itself)
Relative technological performance
Compatibility
Compatibility (norms and values)
Flexibility
Radicalness of innovation
Perceived risk
Communicability
Relative price / cost / effort
Complexity
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Barrier: technical limitations
capital requirement
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user-friendliness
Variation of product shape complexity and cross-sectional

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total production cost
transport time
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Materials supply
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Supply risk (normal and weighted)
E-commerce channel design: tele-manufacturing,
number of supply options

F. Innovation support strategy
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Marketing communications (including Strategic market
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Distribution strategy
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Accelerating technological change and hyper-
Digital Transformation
Expanding influence of east and south
Globalisation
Climate change and environmental degradation
Aggravating resource scarcity
Increasing influence of new governing systems
Changing security paradigm
Increasing significance of migration
Role of governments
Diversifying Inequalities
Availability of energy
Ecological thinking
Potentially less pollution
Less usage of resources

K. Socio-cultural factors
Chances for attractive jobs
Sufficient education and skills development
Educated and skilled employees
Dissemination of AM in society
Regional asymmetries in the eco-innovation system

L. Innovative elements of business model
Imitability, scalability, and integrability
Failure to identify actors/stakeholders
Failure to consider influencing factors

M. Capability to implement business model from firm's perspective
Capability to overcome firms' path dependence and the dominant logic
Focus on business model rather than the product or technology
Capability to develop and strengthen new competencies

N. RRI Indicators (MoRRI)	
Public engagement categorisations	
	PE5 Public engagement performance mechanisms at the level of research institutions
	PE6 Dedicated resources for PE
Science literacy and scientific education categorisations	
	SLSE2 RRI related training
Gender equality categorisations	
	GE1 Share of RPOs with gender equality plans
	GE5 Share of RPOs with policies to promote gender in research content
	GE8 Share of female heads of RPOs
	GE9 Share of gender-balanced recruitment committees at RPOs
Ethics categorisations	
	E1 Ethics at the level of Universities
Open access categorisations	
	OA6 RPO support structures for researchers as regards incentives and barriers for data sharing
Governance categorisations	
	GOV2 Existence of formal governance structures for RRI within RF and RP organisations

Figure 17: total list of factors