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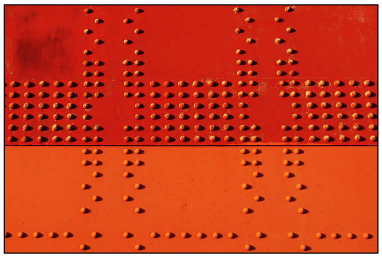

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Insights

Welcome to the June issue of the *Technology Innovation Management Review*. We welcome your comments on the articles in this issue as well as suggestions for future article topics and issue themes.

Carleton University

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Overview

The *Technology Innovation Management Review* (TIM Review) provides insights about the issues and emerging trends relevant to launching and growing technology businesses. The TIM Review focuses on the theories, strategies, and tools that help small and large technology companies succeed.

Our readers are looking for practical ideas they can apply within their own organizations. The TIM Review brings together diverse viewpoints – from academics, entrepreneurs, companies of all sizes, the public sector, the community sector, and others – to bridge the gap between theory and practice. In particular, we focus on the topics of technology and global entrepreneurship in small and large companies.

We welcome input from readers into upcoming themes. Please visit timreview.ca to suggest themes and nominate authors and guest editors.

Contribute

Contribute to the TIM Review in the following ways:

- Read and comment on articles.
- Review the upcoming themes and tell us what topics you would like to see covered.
- Write an article for a future issue; see the author guidelines and editorial process for details.
- Recommend colleagues as authors or guest editors.
- Give feedback on the website or any other aspect of this publication.
- Sponsor or advertise in the TIM Review.
- Tell a friend or colleague about the TIM Review.

Please contact the Editor if you have any questions or comments: timreview.ca/contact

About TIM

The TIM Review has international contributors and readers, and it is published in association with the Technology Innovation Management program (TIM; timprogram.ca), an international graduate program at Carleton University in Ottawa, Canada.

Editorial: Insights

Chris McPhee, Editor-in-Chief

Welcome to the June 2018 issue of the *Technology Innovation Management Review*. The authors in this issue share insights on fostering an entrepreneurial culture for innovation within a large organization, developing business models for 3D printing technology, understanding the evolving roles of living labs and innovation integrators in civic innovation systems, and encouraging university–industry collaboration through jointly organized doctoral programs.

In the first article, **Dev Dutta** from the University of New Hampshire in the United States examines twenty years of Amazon's Letters to Shareholders to gain insights into the company's entrepreneurial culture. The content analysis of these historical documents identified that Amazon's entrepreneurial culture has celebrated a spirit of "self-competition" and has encouraged ongoing innovation throughout the company's lifecycle by embracing ideas such as a "day 1 mentality", "customer centricity", and a "human capital focus". The study findings have useful insights for entrepreneurs, founding teams, and corporate managers engaged in developing an entrepreneurial culture within their own organizations.

Next, **Christina Öberg**, **Tawfiq Shams**, and **Nader Asnafi** from Örebro University in Sweden examine the literature on 3D printing technology and additive manufacturing from a business model perspective. Based on their findings from a review of 116 journal articles, they argue that firms must take a more holistic view of the challenges and opportunities arising from additive manufacturing, especially with respect to interactions with customers and partners, cost structures, and required competences. They also identify several promising research streams to better understand the impact of additive manufacturing on business models.

Then, **Matthew Claudel** from the Massachusetts Institute of Technology (MIT) in the United States considers the evolution of civic innovation systems with a focus on two organizational models: living labs and innovation integrators. He observes that such organizations commonly act as "hubs" within their wider ecosystem, at least initially. Over time, their roles evolve as a result of changes in their surrounding urban contexts, and the task of developing urban technology is then no longer the responsibility of a single hub organization – it becomes a collaborative goal shared by multiple actors on a project-by-project basis. Claudel argues that we should look beyond these individual organizations to consider the city as a sociotechnical system, and we should adjust our practices and theoretical frameworks accordingly.

Finally, **Leena Kunttu** from the University of Vaasa, **Essi Huttu** from DIMECC Ltd, and **Yrjö Neuvo** from Aalto University in Finland, illustrate how doctoral students and graduates can facilitate university–industry collaboration by acting as boundary spanners. Drawing insights from three jointly organized doctoral education and postdoctoral mobility programs, the authors show how industrial firms may facilitate the transfer of academic knowledge to industry to the benefit of individuals and organizations on both sides of the university–industry boundary.

In July, we will feature articles on **Innovation Management** by authors from the ISPIM community. ISPIM (ispim-innovation.com) – the International Society for Professional Innovation Management – is a network of researchers, industrialists, consultants, and public bodies who share an interest in innovation management. The TIM Review and its associated graduate program at Carleton University, the TIM Program (timprogram.ca), are pleased to be extending our ongoing partnership with ISPIM by hosting **ISPIM Connects Ottawa**, a three-day event that will bring together top international innovation managers, researchers, and thought leaders to share insights on local and global innovation challenges. The July issue of the TIM Review will include further details of the event and its call for submissions. ISPIM Connects Ottawa will be held from April 7–10, 2019 in Ottawa, Canada.

For future issues, we are accepting general submissions of articles on technology entrepreneurship, innovation management, and other topics relevant to launching and growing technology companies and solving practical problems in emerging domains.

Please contact us (timreview.ca/contact) with potential article topics and submissions, and proposals for future special issues.

Chris McPhee
Editor-in-Chief

Editorial: Insights

Chris McPhee

About the Editor

Chris McPhee is Editor-in-Chief of the *Technology Innovation Management Review*. Chris holds an MASc degree in Technology Innovation Management from Carleton University in Ottawa, Canada, and BScH and MSc degrees in Biology from Queen's University in Kingston, Canada. He has nearly 20 years of management, design, and content-development experience in Canada and Scotland, primarily in the science, health, and education sectors. As an advisor and editor, he helps entrepreneurs, executives, and researchers develop and express their ideas.

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Keywords: entrepreneurship, culture, Amazon, startup, 3D printing, additive manufacturing, business models, living labs, innovation integrators, civic innovation, sociotechnical systems, university–industry collaboration, boundary spanning, knowledge transfer

In Competition with Oneself: A Qualitative Inquiry into Amazon's Entrepreneurial Culture

Dev K. Dutta

> *We've had three big ideas at Amazon that we've stuck with for 18 years, and they're the reason we're successful: Put the customer first. Invent. And be patient.*
>
> Jeff Bezos
> Technology entrepreneur, investor, and philanthropist
> Founder, Chairman, and CEO of Amazon

Utilizing a historiographic approach based on Amazon's Letters to Shareholders (LTS) over a twenty-year timeframe (1997–2016), this article identifies the discerning features of the company's entrepreneurial culture that enabled it to become one of today's most innovative organizations. A content analysis of the LTS while coding for underlying theoretical themes reveals Amazon's entrepreneurial culture has been increasingly celebrating a spirit of "Self-Competition", and by embracing ideas such as "Day 1 Mentality", "Customer Centricity", and "Human Capital Focus". The study findings have useful insights for entrepreneurs, founding teams, and corporate managers engaged in developing an entrepreneurial culture within their own organizations.

Introduction

In 2018, Amazon became the third-most valuable company at the bourses, forging ahead of Microsoft, and just behind Apple and Alphabet. This is remarkable, given that the company only started earning profits in 2002 – eight years after its inception. Throughout the first several years of its existence, Amazon pursued a strategy of aggressive growth by broadening its business portfolio (from being an online retailer of books to a retailer of "everything") and through multiple acquisitions. During this time, even though financial analysts raised questions about Amazon's high-risk growth strategy, the company sustained investor and customer interest, with investor sentiments fluctuating from "investor patience" to an "investor recklessness" to hold on to the company stock even when Amazon's performance suggested they should do otherwise (Cengage, 2017). Clearly, customers and investors loved Amazon's daring experiments with radical innovation in redefining the very concept of online retail. The question then arises: how were Amazon and, notably, its CEO and Chief Founder Jeff Bezos able to create a highly enabling entrepreneurial culture such that the organization remained customer-focused, inventive, and "patient"?

For a business firm, what constitutes entrepreneurial culture? More importantly, as the organization progresses through its lifecycle and becomes large, and therefore, bureaucratic – with established processes, structures, routines and norms – how does it continue to maintain an entrepreneurial culture? This is the focus of the present study. Using a qualitative approach anchored on a study of historical documents, notably Amazon's Letters to Shareholders (LTS) over a twenty-year timeframe (1997–2016), this study aims to identify the attributes or discerning characteristics of what constitutes an innovating firm's entrepreneurial culture.

Entrepreneurial Culture: Why It Matters

Contrasted with entrepreneurship in nascent firms or new ventures, corporate entrepreneurship, – or, in other words, *continued entrepreneurship in large corporations* (Sakhdari, 2016) – has long been a research topic of interest among entrepreneurship scholars (e.g., Covin & Miles, 1999). This is especially the case because preserving the firm's entrepreneurial proclivity becomes especially difficult as the organization grows in size and age.

In Competition with Oneself: A Qualitative Inquiry into Amazon's Entrepreneurial Culture *Dev K. Dutta*

According to scholars, corporate entrepreneurship is generally noticed in three forms: i) creation of a new business within an extant firm, ii) transformation and strategic renewal of an extant firm, and iii) when an extant firm changes the rule of the game within an industry by engaging in Schumpeter's (1934) idea of the process of creative destruction, and repeatedly (Covin & Miles, 1999; Stopford & Baden-Fuller, 1994). The last scenario is especially important because it requires the firm to rise up to the challenge of "…rejuvenating or purposefully redefining organizations, markets, or industries in order to create or sustain a position of competitive superiority…" (Covin & Miles, 1999). To achieve this, the firm's efforts must be directed at building and sustaining an organization-wide entrepreneurial culture.

Scholars (e.g., Russell & Russell, 1992) have emphasized the critical importance of an enabling organizational culture in shaping and enhancing entrepreneurial activities within the firm. Russell and Russell (1992) identified the following as the essential characteristics of an entrepreneurial culture: i) value for innovation as a practice and source of competitive advantage; ii) focus on creativity and creative pursuits on the part of organizational members; iii) resource support for creativity and innovation; iv) information-sharing among members; v) risk-taking and tolerance for failure; vi) an openmindedness toward new ideas and initiatives; and vii) a culture embracing implementation of innovation, in all forms and at all levels of the organization. However, in spite of the early research on attempts to understand the specific characteristics of entrepreneurial culture, this field of inquiry did not gain much traction subsequently. Rather, the interest of scholars shifted more toward defining and understanding entrepreneurial orientation – a related concept discussed in the next section. Further, some of the follow-up research deviated from the more broad-based idea of entrepreneurial culture and tended to focus more explicitly on how firms specifically create a culture that supports innovation. In their study, Chandler, Keller, and Lyon (2000) examined the determinants of an innovation-focused organizational culture. The authors found that such a culture is enhanced when: i) employees trust and perceive support from the firm's management, ii) the organizational reward system supports innovation, and iii) excessive work pressure that tends to stifle individual and team creativity is minimized. Concurring with Russell and Russell (1992) that innovation is at the heart of a company's entrepreneurial culture, Covin and Miles (1999) note, "…there is [far] more to corporate entrepreneurship than innovation." The question is what might be the additional characteristics of a corporation's entrepreneurial culture?

Entrepreneurial Culture: Same or Different from Entrepreneurial Orientation?

While studying a firm's entrepreneurial culture, the attention of scholars shifted over the last two decades toward the concept of entrepreneurial orientation. The idea of entrepreneurial orientation was initially introduced by Covin and Prescott (1985), followed by two articles now considered seminal in the field of entrepreneurial orientation research: i) Coven and Slevin (1989), in which the authors defined entrepreneurial orientation as "entrepreneurial strategic posture", and ii) Lumpkin and Dess (1996), in which the authors extended the conceptual definition of entrepreneurial orientation and attempted to establish its links with firm performance. Since then, there has been a burgeoning interest in entrepreneurial orientation among scholars, so much so that Gupta and Dutta (2016) classify the period 1996–2008 as the "growth phase" in research into entrepreneurial orientation. Beginning with developing and refining measures of the construct of entrepreneurial orientation, researchers tested its relationships with other firm-level constructs such as performance, resource allocations, environmental factors, and firm behaviour, among others (Gupta & Dutta, 2016; Rauch et al., 2009; Wales, 2016; Wales et al., 2013).

Covin and Wales (2018) define entrepreneurial orientation as "an attribute of an organization that exists to the degree to which that organization supports and exhibits a sustained pattern of entrepreneurial behavior reflecting incidents of proactive new entry." Whereas the Covin and Slevin (1989) conceptualization of entrepreneurial orientation considers the firm's proclivity for risk taking, innovativeness, and proactiveness, the Lumpkin and Dess (1996) conceptualization adds two more firm-level characteristics – autonomy and competitive aggressiveness – to Covin and Slevin's (1989) definition. Covin and Wales (2018) note that the first conceptualization focuses on what is "common" among entrepreneurial firms whereas the second conceptualization identifies what makes them "different". Authors engaging in empirical work have tended to be equally disposed toward embracing either conceptualization of entrepreneurial orientation (Rauch et al., 2009; Wales, 2016). And yet, despite the enormous progress in the literature on entrepreneurial orientation, questions remain – both as to what factors constitute entrepreneurial orientation and how it relates to other organizational constructs. Thus, Gupta and Dutta (2018) identify several myths that continue to persist in the literature on entrepreneurial orientation: i) that the nature of the relationship between entrepreneurial orientation and performance is clear and well established; ii) that there is high agreement on the dimensions of entrepreneurial orientation; and iii) that the measurement of entrepreneurial orientation is well understood. In the circumstances, even though early research did lay a strong foundation of what constitutes a firm's entrepreneurial culture, this was overtaken later by a new, emerging stream of research focusing on entrepreneurial orientation and the latter's organizational impact. Clearly, entrepreneurial culture is not the same as entrepreneurial orientation, even though the two constructs share quite a few overlaps. A greater concern arises from the finding that since the relationship between entrepreneurial orientation and performance is not stable, it is important to identify the specific elements of an organization's entrepreneurial culture, which could lead to an exceptional performance outcome year after year, such as that achieved by Amazon.

According to Sakhdari (2016), it is important to distinguish between corporate entrepreneurship (i.e., the actual entrepreneurial acts and results) and entrepreneurial orientation (i.e., the firm's overall predispositions towards strategies, structures, practices, and activities that foster entrepreneurship). I suggest that an in-depth study of what constitutes a firm's entrepreneurial culture will offer insights in this regard, especially as to how the organization navigates from entrepreneurial orientation as the firm-level strategic orientation toward corporate entrepreneurship and organizational performance outcomes. Further, this would become extremely relevant in the context of a company such as Amazon, which continually leaves its competitors far behind in terms of corporate entrepreneurship. Accordingly, these ideas constitute the theoretical basis for undertaking the present study.

Research Design and Methods

Data source

In order to identify the defining characteristics of the firm's entrepreneurial culture going beyond innovation, a qualitative study of Amazon could have been adopted a range of qualitative methods, going from ethnography (e.g., field observation, interviews, document analysis) to historiometric methods (e.g., content analysis of archival records). For the purpose of this research, I decided to adopt the latter approach, primarily based on a longitudinal study and assessment of a critical documentation generated by the company: Letters to Shareholders (LTS). A qualitative research strategy based on studying archival records is highly suitable for this study. Prior research notes that LTS can be a useful way of accessing managerial cognition and worldview in large firms, particularly over a considerable time span (Bettman & Weitz, 1983; Prasad & Mir, 2002). Although information available in the LTS may be critiqued based on the concept of attitudinal fallacy (Jerolmack & Khan, 2014; Vaisey, 2014), there is no denying that LTS represent the views of the firm's upper echelons (top management) and serve as a powerful expression of the organization's strategic orientation to the world at large, even if such descriptions are carefully constructed.

Incorporated in 1994, Amazon became public in 1997, when it became required for the company to submit LTS as part of its annual filings to Securities and Exchange Commission. At the time of commencement of this study, the latest year for which Amazon's LTS were published is 2016. Accordingly, I used a twenty-year timeframe: 1997–2016. To locate the LTS, I utilized two databases: Mergent Online and Hoover's Online. I compared the two sets of LTS for every year of the study period, in order to ensure that they were the same document. Upon completion of this step, I had 20 LTS for Amazon, from 1997 until 2016. Second, I also searched the two databases for additional information on the company and was able to download several documents providing the history of evolution of the company and its expansion over time, including through acquisitions. Together, the LTS and the associated documentation constitute a significant repository of Amazon's top management strategic intent and orientation over a long and significant period in the company's lifecycle. As such, the information in these documents could serve as pointers to Amazon's entrepreneurial culture, which the company's top management was developing over this fairly long period of time.

Analytical methods

After developing a high level of familiarity with Amazon's evolution and history (including the milestones achieved by the organization through 1997–2016) utilizing the background documentation gathered, I embarked on content analysis of the LTS in order to examine evidence of the company's entrepreneurial culture, if any. As the first step, this involved engaging in a process of open coding, where I marked any/all passages across the 20 LTS that caught my attention as being in some ways descriptive of the company's strategic orientation and culture. This resulted in the identification of 91 passages over the 20 LTS as potentially interesting. As the next step, I began analyzing the 91 passages, now looking for any potential patterns that seemed to crystallize, through the process of theoretical coding. Going back and forth through this step multiple times led to the identification of four distinct themes, which are the attributes of Amazon's entrepreneurial culture.

For two out of the four themes, "Self-Competition" and "Customer Centricity", two trained coders (the author and a colleague who was otherwise unfamiliar with the study) independently coded two (out of the 20) LTS (2015 and 2016). The agreement between the two coders was 5 out of 7 (71%) for Self-Competition and 5 out of 6 (83%) for Customer Centricity. In other words, it appears the coding strategy adopted was indeed able to identify the emergence of dominant themes in Amazon's entrepreneurial culture.

Findings

Company background

Amazon was incorporated in July 1994 in the state of Washington in the United States. It was later reincorporated in Delaware in June 1996. With 566,000 full-time employees, revenues of $193.19 Billion USD, and a market capitalization of $767.20 Billion USD (as of 12/31/2017), Amazon is the largest company in the specialty retail sector.

As a firm aspiring to be the first choice of customers in "anything retail", Amazon serves consumers, sellers, developers, enterprises, and content creators via its retail websites. In addition, the firm manufactures and sells electronic devices. Its Marketplace platform provides programs that enable third-party sellers to sell their products on its websites, including authors, musicians, filmmakers, app developers, and others to publish and sell content. Further, one of its associated business divisions, Amazon Web Services (AWS), provides access to technology infrastructure to a wide range of other companies, both large and small. Finally, Amazon also provides services, such as advertising services and co-branded credit card agreements. Figure 1 depicts Amazon's market performance vis-à-vis Standard & Poor 500 during 1997–2016.

Jeff Bezos: Amazon's CEO and Chief Founder

In 1994, Jeff Bezos left his job as the Vice President at D.E. Shaw in New York. His idea was to set up a new venture to take books that had not found favour with the D.E. Shaw Management and sell them online. Bezos moved to Seattle, where he developed a business plan and set up Amazon out of his garage. He chose Seattle because of its large concentration of high-tech workers and proximity to a large book distribution centre in Oregon. Over the next several years, Bezos would grow Amazon aggressively, constantly diversifying the firm's portfolio of services and carefully acquiring startups that would allow Amazon to grow inorganically. By 1996, Amazon became a publicly limited company though it did not post its first annual profit until 2003. In 1997, Amazon became the first Internet-based retailer to reach the milestone of 1 million customers. It would not be an overstatement to say that Bezos' maverick innovative persona and visionary leadership had a deep imprint

Figure 1. Amazon's Market Performance vis-à-vis S&P 500 (1997–2016) (Source: Mergent Online)

on Amazon and the organization's entrepreneurial culture. For his achievements, in 1999 Bezos was recognized as the *Time* Person of the Year (*Time,* 1999).

Amazon's Entrepreneurial Culture: Dominant Themes

Scholars have noted the importance of corporate entrepreneurship as a possible answer as to why some large firms continue to be entrepreneurial over their lifecycle whereas others lose that entrepreneurial edge. Yet, to date, very limited research exists on what defines an organization-wide entrepreneurial culture. Rather, so far, the research focus seems to have been toward exemplifying different "types" of corporate entrepreneurship. As far as entrepreneurial culture goes, it is taken to be synonymous with risk-taking and a relentless focus on innovation.

Amazon is a highly innovative company. In fact, in 2017, it was identified by *Fast Company* as the world's most innovative company. And, indeed, Amazon's LTS contain numerous references to different innovations the organization introduced over the timeframe of this research (1997–2016) and how this emphasis on innovation paid off, both in terms of expanding Amazon's market power as well as revenues. However, as already noted, the focus of the present research was to look beyond Amazon's emphasis on innovation and identify possible additional aspects of its entrepreneurial culture by going below the surface, and hopefully identifying how exactly an innovative spirit is fostered within the firm. In that context, deep analysis of the LTS data to look for patterns brought up four distinct themes. Together, these constitute Amazon's entrepreneurial culture. Table 1 identifies and defines each of the four themes, and reports the number of quotations noted in the LTS across the four themes; Table 2 provides representative quotations under each theme.

Theme 1: Day 1 Mentality

This first theme is defined as a way of keeping an organization perpetually in the "first-day mode" (characterized by uncertainty, edginess, experimentation, and risk-taking with a high degree of tolerance for failure). Amazon's entrepreneurial culture imbibes the spirit of day-to-day living as a "Day 1 Company", meaning perennially youthful, agile, nimble, and entrepreneurial. In fact, Bezos established the ritual of remembering and constantly reinforcing this credo. The reference to Day 1 was first made in the company's 1997 LTS. By way of practice, the 1997 LTS has been appended to every subsequent LTS released by Amazon, and often with an explicit reference to the 1997 credo in the body of the current year's LTS. The 1997 LTS stated:

> "Amazon passed many milestones in 1997: by year-end, we had served more than 1.5 million customers, yielding 838% revenue growth to $147.8 million, and extended our market leadership despite aggressive competitive entry. But this is Day 1 for the Internet and, if we execute well, for Amazon.com… We believe that a fundamental measure of our success will be the shareholder value we create over the *long term.*"

The immediate next year (1998) drew a reference to this when Bezos stated in the LTS: "It's truly Day 1 for the Internet and, if we execute our business plan well, it remains Day 1 for Amazon.com." It is important to note why Amazon would repeat this thought about Day 1 in its LTS in the years to follow. Organizations seek legitimacy from their constituents and engage in explicit practices to help earn legitimacy (Ashforth & Gibbs, 1990). As I already noted, beginning with 1997, the next few years were a period of explosive (and some would even consider reckless) growth for Amazon. Financial analysts, and even some investors, had begun to express grave doubts about the company's moving into new business segments/markets, new acquisitions, significant addition of employees, and tremendous expansion of business partners. All this time, even as revenue was growing, Amazon was not making any profits. Under these circumstances, it was extremely important for the organization to not only reassure its employees but also external stakeholders (notably the investor community) that this state of affairs is deliberate and perfectly normal. What better way to communicate this to both internal and external stakeholders than by coining the term "Day 1 Culture"? This serves to indicate Amazon deliberately embraced (and in a well-meaning way) an innovative, experimental, trial-and-error, first-day organization – an entrepreneurial culture that only new/young companies experience, and which they lose over time unless they are careful. From assessing the data in the LTS, it is clear the company was making a significant effort to preserve this Day 1 Mentality. Thus, Bezos writes in the 2016 LTS:

> "I've been reminding people that it's Day 1 for a couple of decades. I work in an Amazon building named Day 1, and when I moved buildings, I took the name with me. I spend time thinking about this topic. Day 2 is stasis. Followed by irrelevance. Followed by excruciating, painful decline. Followed by death. And that is why it is always Day 1."

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While studying organizational culture, scholars (e.g., Allaire & Firsirotu, 1984; Thompson et al., 1990) note that, given culture's intangible, diffused nature, many organizations utilize artifacts to depict it. This seems to dovetail nicely with Bezos' reference to the name Day 1 that was coined for an Amazon building, and which he took with him when he moved office.

Theme 2: Customer Centricity

A new venture comes into existence and remains viable if, and only if, it is able to offer something of value (i.e., a unique value proposition) to a significant group of customers (Ireland et al. 2009; Morris et al., 2005). Amazon's Day 1 Mentality makes the organization almost fanatical in terms of how it views and interacts with its customers. Thus, Customer Centricity becomes a second theme of Amazon's entrepreneurial culture. Customer Centricity involves maintaining a relentless and total focus on the customer at all times. Amazon's 2012 LTS begins with the following statement:

> "As regular readers of this letter will know, our energy at Amazon comes from the desire to impress customers rather than the zeal to best competitors… We do work to pay attention to competitors and be inspired by them, but it is a fact that the customer-centric way is at this point a defining element of our culture."

Such a single-pointed gaze and constant focus on the customer, and the customer alone, is what makes Amazon different from its competitors (such as the Walmart). Amazon acknowledges that competitors are very important but believes staying focused on customers uppermost is what will drive innovation as also maintain business success over the long term. Amazon seems to have developed an organization-wide rhythm and understanding that keeps the customer focus at the heart of everything it does. Thus, the 2013 LTS notes: "Amazonians around the world are polishing products and services to a degree that is beyond what's expected or required, taking the long view, reinventing normal, and getting customers to say 'Wow'." Similarly, the 2015 LTS remarks,

> "Many companies describe themselves as customer-focused, but few walk the walk. Most big technology companies are competitor-focused. They see what others are doing, and then work to fast follow. In contrast, 90 to 95% of what we build… is driven by what customers tell us what they want… Our approach to pricing is also driven by our customer-centric culture – we've dropped price 51 times, in many cases before there was any competitive pressure to do so."

Theme 3: Human Capital Focus

Ever since its inception, Amazon has continued to maintain a strategic focus on hiring, nurturing, and retaining the best talent. The theme of Human Capital Focus involves treating people as the most important organizational resource and creating conditions such that they can always perform at their best level. For example, the 1997 LTS noted:

> "Setting the bar high in our approach to hiring has been, and will continue to be, the single most important element of Amazon.com's success…we are working to build something important, something that matters to our customers, something that we can all tell our grandchildren about. Such things aren't meant to be easy. We are incredibly fortunate to have this group of dedicated employees whose sacrifices and passion build Amazon.com."

Table 1. Dominant themes, definitions, and number of occurrences of quotations relating to each theme in Amazon's LTS (1997–2016)

Theme	Definition	Occurrences
1. Day 1 Mentality	Keeping the organization perpetually in the "first-day mode" (characterized by uncertainty, edginess, experimentation, risk-taking, and tolerance for failure)	24
2. Customer Centricity	Relentless and total focus on the customer at all times	46
3. Human Capital Focus	Treating people as the biggest organizational resource and creating conditions such that they can perform their best	21
4. Self-Competition	The understanding that ultimately one is competing with oneself and not any other players in the market	6

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Table 2. Amazon's LTS: Dominant themes and representative quotations

1. Day 1 Mentality
"It is truly Day 1 for the Internet and, if we execute our business plan well, it remains Day 1 for Amazon.com." (1998)
"Though it's sometimes hard to imagine with all that has happened in the last five years, this remains Day 1 for e-commerce…" (1999)
"Our passion for pioneering will drive us to explore narrow passages, and unavoidably, many will turn out to be blind alleys. But – with a bit of good fortune – there will also be a few that open up into broad avenues." (2012)
"I've been reminding people that it's Day 1 for a couple of decades. I work in an Amazon building named Day 1, and when I moved buildings, I took the name with me. I spend time thinking about this topic… Day 2 is stasis. Followed by irrelevance. Followed by excruciating, painful decline. Followed by death. And that is why it is always Day 1… I'm interested in the question, how do you fend off Day 2? What are the techniques and tactics? How do you keep the vitality of Day 1, even inside a large organization?... Here's a starter pack of essentials for Day 1 defense: customer obsession, a skeptical view of proxies, the eager adoption of external trends, and high-velocity decision-making." (2016)
2. Customer Centricity
"We will continue to focus relentlessly on customers." (1997)
"We intend to build the world's most customer-centric company… I constantly remind our employees to be afraid, to wake up every morning terrified. Not of our competition, but of our customers. Our customers have made our business what it is, they are the ones with whom we have a relationship, and they are the ones to whom we owe a great obligation." (1998)
"Our vision is to use this platform to build Earth's most customer-centric company, a place where customers can come to find and discover anything and everything they might want to buy online." (1999)
"In this turbulent global economy, our fundamental approach remains the same. Stay heads down, focused on the long term and obsessed over customers… If we can identify a customer need and if we can further develop conviction that that need is meaningful and durable, our approach permits us to work patiently for multiple years to deliver a solution." (2008)
"Start with customers, and work backwards. Listen to customers, but don't *just* listen to customers – also invent on their behalf… we can assure you that we'll continue to obsess over customers. We have strong conviction that that approach – in the long term – is every bit as good for owners as it is for customers." (2009)
"Our energy at Amazon comes from the desire to impress customers rather than the zeal to best competitors… We do work to pay attention to competitors and be inspired by them, but it is a fact that the customer-centric way is at this point a defining element in our culture." (2012)
"There are many ways to center a business. You can be competitor focused, you can be product focused, you can be technology focused, you can be business model focused, and there are more. But in my view, obsessive customer focus is by far the most protective of Day 1 vitality." (2016)
3. Human Capital Focus
"When I interview people I tell them, "You can work long, hard, or smart, but at Amazon.com you can't choose two out of three… we are working to build something important, something that matters to our customers, something that we can tell our grandchildren about. Such things aren't meant to be easy. We are incredibly fortunate to have this group of dedicated employees whose sacrifices and passion build Amazon.com." (1997)
"Around the world, amazing, inventive, and hard-working Amazonians are putting customers first. I take great pride in being part of this team." (2008)
"We have on our team some of the most sophisticated technologists in the world – helping to solve challenges that are right on the edge of what is possible today." (2010)
"I'm so proud of what all the teams here at Amazon have accomplished on behalf of customers this past year. Amazonians around the world are polishing products and services to a degree that is beyond what's expected or required, taking the long view, reinventing normal, and getting customers to say, 'Wow…' We challenge ourselves to not only invent outward facing features, but also find better ways to do things internally – things that will both make us more effective and benefit our thousands of employees around the world." (2013)
"Three years ago we launched an innovative employee benefit – the Career Choice program, where we pre-pay 95% of tuition for employees to take course for in-demand fields such as airplane mechanic or nursing, regardless of whether the skills are relevant to a career in Amazon. The idea was simple: enable choice." (2014)
"As I meet with teams across Amazon, I am continually amazed at the passion, intelligence and creativity on display." (2015)

Table 2. ***(continued)*** Amazon's LTS: Dominant themes, definitions, and representative quotations

4. Self-Competition
"We must be committed to constant improvement, experimentation, and innovation in every initiative. We love to be pioneers, it's in the DNA of the company, and it's a good thing too, because we'll need that pioneering spirit to succeed." (1998)
"Many of the problems we face have no textbook solutions, and so we – happily – invent new approaches." (2010)
"When we're at our best, we don't wait for external pressures. We are *internally* driven to improve our services, adding benefits and features, before we have to. We lower prices and increase value for customers before we have to. We invent before we have to." (2012)
"Nothing gives us more pleasure at Amazon than "*reinventing normal*" – creating inventions that customers love and resetting their expectations for what normal should be." (2013)

From the above quotation, it is clear that Amazon sees its focus on human capital not just in terms of creating an enabling organizational culture and providing resources so that employees perform at their highest potential but also demand from the employees that they do so. Setting high expectations coupled with creating a nurturing, enabling culture are what make Amazon's entrepreneurial culture unique. Many other competitors do create within their organizational boundaries a culture focused on innovation, risk-taking, high performance, and productivity. Amazon takes this to the next level by insisting that its employees go out of their way in creating value for customers. This is what makes Amazon different.

Theme 4: Self-Competition

A fourth theme in Amazon's entrepreneurial culture is Self-Competition – an understanding that ultimately one is competing with oneself and not with anyone else in the market. Throughout the LTS, there are explicit references to how Amazon thinks of itself as the company's biggest, and perhaps, only, competitor. In the 2012 LTS, Amazon asserts: "We are *internally* driven to improve our services… before we have to." This idea of competing with oneself, even if idealistic, has very tangible benefits. Thus, later in the same LTS, Amazon recognizes: "On the other hand, internal motivation – the drive to get the customer to say 'Wow' – keeps the pace of innovation fast." Again, in the 2013 LTS, Amazon states explicitly:

> "We challenge ourselves to not only invent outward facing features, but also to find better ways to do things internally – things that will both make us more effective and benefit our thousands of employees around the world."

In analyzing the data, an interesting observation emerged with regard to Self-Competition. As Table 2 reveals, the first time Amazon embraced this attribute as part of its entrepreneurial culture was in 1998, when it identified itself as a pioneer operating with a missionary zeal to create products that would delight customers. Thereafter, Self-Competition did not explicitly feature in the LTS until after 2009, by which time Amazon had consolidated and integrated its many acquisitions into the mainstream organization, also building up significant market share and profits. At that stage in its lifecycle, it would be fair to state that Amazon really had no near competitors in the market. What does a company do if it cannot benchmark itself against competition in order to continuously improve, and yet wishes to constantly excel? For Amazon, the way to go forward was to further enhance its entrepreneurial culture by transforming its pioneering/missionary orientation into the intriguing concept of Self-Competition. Thus, the 2012 LTS boldly asserts, "When we're at our best, we don't wait for external pressures. We are internally driven to improve… we invent before we have to." Similarly, the following year's LTS celebrates Self-Competition by stating, "Nothing gives us more pleasure at Amazon than *"reinventing normal"* – creating inventions that customers love and resetting their expectations for what normal should be."

Further, the data analysis indicates that if there is one overarching attribute that exemplifies Amazon's entrepreneurial culture at present, it is the idea of Self-Competition. This cultural attribute is not only ingrained in Amazon's DNA but also fundamental to the company's way of operating. With Self-Competition defining Amazon's overall entrepreneurial culture, the other three themes – Day 1 Mentality, Customer Centricity, and Human Capital Focus – directly follow. The concept of Self-Competition leads Amazon to maintain the Day 1 Mentality, embrace Customer-Centricity, and concentrate on Human Capital Focus. This becomes clear upon considering the quotations under the Self-

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Competition theme in Table 2, which incorporate words and phrases such as "pioneers" and "pioneering spirit to succeed" (representing Day 1 Mentality), "increase value for customers" (highlighting Customer Centricity), and "committed to constant improvement" and "we're at our best" (indicating a deep Human Capital Focus). In turn, developing and operating with an entrepreneurial culture anchored in Day 1 Mentality, Customer Centricity, and Human Capital Focus, helps Amazon to truly embrace Self-Competition, thus reinforcing this aspect of the organization's entrepreneurial culture.

Conclusion

Using a qualitative approach through content analysis of historical documents in the form of LTS, this research explored the specific attributes of Amazon's entrepreneurial culture by taking a broad-based view. First, going beyond what current entrepreneurship literature has tended to identify as the attributes of an entrepreneurial culture reflecting in the firm's entrepreneurial orientation (e.g., creativity, experimentation, innovation, risk taking, and tolerance for failure), the study findings indicate that Amazon's entrepreneurial culture is far more nuanced and complex, incorporating within itself three specific themes: Day 1 Mentality, Customer Centricity, and Human Capital, each reinforcing the other, and together leading Amazon to demonstrate the intriguing fourth theme of Self-Competition. The study findings contribute to illuminating entrepreneurial culture in large firms, which is an understudied field of research.

Second, the enhanced understanding of these specific attributes of an entrepreneurial culture opens up possibilities of future research, including survey-based (quantitative) on modelling and testing hypothesized relationships. Other additional avenues of future research, within the qualitative domain itself, could consider adopting fieldwork using ethnographic methods to understand the nature and characteristics of organizational processes that enable Self-Competition, Day 1 Mentality, Customer Centricity, and Human Capital Focus to come to fruition within Amazon. Additionally, a second area of future research to expand the understanding could adopt multiple case studies to compare and contrast the respective attributes of entrepreneurial culture in Amazon versus other well-known technology companies such as Apple, Microsoft, Facebook, and Alphabet (Google).

Finally, the outcomes of the present research also may be useful to practitioner managers in other large firms. The insights give them knowledge about specific attributes and related processes that lead to establishing an entrepreneurial culture, thus helping them to keep their own companies entrepreneurial.

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Additive Manufacturing and Business Models: Current Knowledge and Missing Perspectives

Christina Öberg, Tawfiq Shams, and Nader Asnafi

> *With 3D printing, complexity is free. The printer doesn't care if it makes the most rudimentary shape or the most complex shape, and this is completely turning design and manufacturing on its head as we know it.*
>
> Avi Reichental
> CEO, 3D Systems

Additive manufacturing, that is 3D printing technology, may change the way companies operate their businesses. This article adopts a business model perspective to create an understanding of what we know about these changes. It summarizes current knowledge on additive manufacturing within management and business research, and it discusses future research directions in relation to business models for additive manufacturing. Using the scientific database Web of Science, 116 journal articles were identified. The literature review reveals that most research concerns manufacturing optimization. A more holistic view of the changes that additive manufacturing may bring about for firms is needed, as is more research on changed value propositions, and customer/sales-related issues. The article contributes to previous research by systematically summarizing additive manufacturing research in the business and management literature, and by highlighting areas for further investigation related to the business models of individual firms.

Introduction

In recent years, interest has risen in additive manufacturing, that is, layer-based 3D printing of goods (Conner et al., 2014; Go & Hart, 2016). Although concerns are still placed on the challenges of getting the technology to work (Gardan, 2016), several industry actors have started to explore the business potential of additive manufacturing. Research largely remains focused on the technological advancement, although voices have recently been raised about how additive manufacturing research needs to be integrated with industry (Simpson et al., 2017), and thereby affecting business practices. In short, additive manufacturing is expected to change the ways in which business is run (Brennan et al., 2015; MacCarthy et al., 2016).

This article focuses on the meaning of additive manufacturing for individuals firms by adopting a business model perspective (Osterwalder & Pigneur, 2010; Zott et al., 2011) on additive manufacturing. Business models refer to conceptual descriptions of a company and its business logic (Osterwalder et al., 2005; Zott et al., 2011), that is, how the company is organized and earns its income. Business *modelling* describes change processes related to how business is pursued (Zott & Amit, 2010). For additive manufacturing, such changes would follow from the prospective for local manufacturing (e.g., Rogers et al., 2016), but also from completely new designs and materials (Sharma et al., 2017), and companies may try to reposition themselves along the supply chain as their current positions are challenged by local manufacturing and home-based production, for instance (Shams & Öberg, 2017), in turn affecting the business models.

This article addresses whether companies' business models and changes to them are considered in the present literature on additive manufacturing, and how changes to individual companies' operations can be understood from present research. The article presents a literature review on additive manufacturing with the underlying question of whether and how the research indicates new business models of companies, the transformation of current business models, or the development of completely new ones. The purpose of the

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article is *to summarize current knowledge on additive manufacturing within management and business research, and to discuss future research directions in relation to business models for additive manufacturing.*

The article contributes to previous research by examining how the emergence of additive manufacturing affects existing business models. It further points out research gaps in the intersection of additive manufacturing and business models. The contributions are important due to the emerging practical interest in additive manufacturing (Simpson et al., 2017) and because the literature specifically focusing on business models and their changes related to additive manufacturing has not previously been systematically summarized and analyzed.

The rest of the article is structured as follows. After this introduction, the theoretical building block of business models is presented, followed by the research design. Findings from the literature review are described and analyzed by looking into business model traces in the literature. The article ends with conclusions and a description of a future research agenda on additive manufacturing linked to business models.

Business Models

Business models describe a company's business logic: what it does, how it is organized, how it earns its income, and how it reaches those resources needed (Osterwalder & Pigneur, 2010). They thereby adopt a holistic perspective on the company's business (Bolton & Hannon, 2016) and link various activities together (Zott & Amit, 2010) at the centre of what is offered to customers (Margretta, 2002; Teece, 2010). In the general description of business models, one key aspect is the border between activities of the company and those of external parties. Research has here referred to how business models may be open or include border-spanning activities (Vanhaverbeke & Chesbrough, 2014), thus emphasizing the business model's connection to supply-chain decisions (Lambert et al., 1998; Nordin et al., 2010) in how the business model includes make-or-buy decisions related to core and strategic competences of the firm.

The literature provides several ways to describe business models, often reflected as canvas and non-canvas models. The canvas models refer to illustrative descriptions of a company's different processes (such as resource provision, value creation, and customer offering, as in Osterwalder et al., 2005), whereas the non-canvas models refer to textual descriptions of, for instance, activities (such as the description of content, structure, and governance of activities, as in Zott & Amit, 2010). The business model canvas (Osterwalder & Pigneur, 2010) describes key resources, activities, and partners on the providing side; the value proposition (the offering); customer relationships, segments, and channels on the sales side; along with revenue streams and cost structures. Key resources, activities, and partners describe what is needed to produce the company's services or products, and what part of these are made by the company or other companies. The value proposition reflects how the company puts forth its products or services to customers that are then to decide their value. It includes the product, price, extended product, etc., and is what creates the competitive edge of the company's offering. How the customers are reached is understood through descriptions of channels (such as through independent retailers, the Internet, etc.), whereas segments describe what portion of the market the company aims to reach. Customer relationships, lastly, reflect the relational or transactional characteristic of exchanges along with how resale is created. Cost structures define the types of costs (fixed, variable, etc.) that the company's operations create, whereas revenue streams reflect structures of payments and financial deals with customers.

Business *modelling* puts focus on the development of new business models or changes to current ones, resulting from opportunities in the market as well as challenges manifested in awareness of contextual change (Johnson et al., 2008). In the case of additive manufacturing, new technologies may constitute challenges as well as opportunities for companies linked to rapid prototyping, rapid tooling, direct manufacturing, and home fabrication (Rayna & Striukova, 2016), for instance, which would affect and require changes to the company's business model.

As a means to analyze previous additive manufacturing literature in the business and management research, this article juxtaposes the ideas of Osterwalder and Pigneur (2010) with those of Zott and Amit (2010), so as to capture business models (Osterwalder & Pigneur, 2010) and changes to them (Zott & Amit, 2010). Figure 1 outlines this framework. Osterwalder and Pigneur's (2010) framework consists of the following: key resources, key partners, key activities, the value proposition, customer relationships, customer segments, channels, revenue streams, and cost structures. Zott and Amit's (2010) description of content, structure, and governance refers to what activities are pursued (content), how they are linked (structure), and who performs the activities (governance), so as to capture their changes.

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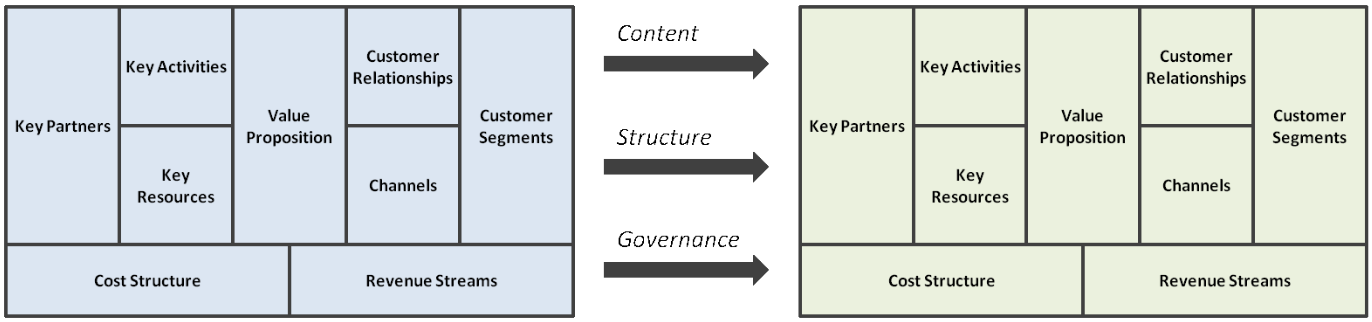

Figure 1. Analytical framework

Research Design

The article is based on a systematic literature review (cf. Tranfield et al., 2003) conducted as two separate searches so as to capture business models and business model changes in the additive manufacturing and 3D printing literature. The first search provided a very limited number of articles, therefore a second search focused more broadly on additive manufacturing and 3D printing in the business, management, and operational management literature to see whether any traces of business model parts (Osterwalder & Pigneur, 2010) were described in that literature. Both searches used the academic database Web of Science. The literature reviews were delimited to journal articles (thus excluding conference proceedings, etc.). The reason for using the search terms “additive manufacturing” and “3D printing”, respectively, was how an initial search only including additive manufacturing failed to capture some of the predefined relevant articles connecting related methods to business models.

The first search, which focused on “additive manufacturing” or “3D printing” in combinations with “business model” or “business logic” resulted in a total of seven journal articles for the years 2014–2017 (starting date set by occurrence in the database, end date defined to capture entire years):

1. Bogers, Hadar, and Bilberg (2016)
2. Flammini, Arcese, Lucchetti, and Mortara (2017)
3. Holzmann, Breitenecker, Soomro, and Schwarz (2017)
4. Kurman (2014)
5. Laplume, Anzalone, and Pearce (2016a)
6. Pisano, Pironti, and Rieple (2015)
7. Rayna and Striukova (2016)

Among these articles, the one by Flammini and co-authors (2017) does not describe additive manufacturing beyond exemplifying it as one of several technologies, leaving only six articles for further inclusion.

Based on the limited number of articles resulting from the initial search, the second search was conducted, this time focusing on the description of any of the parts of the business model canvas (Osterwalder & Pigneur, 2010) or changes thereto as means to code articles in the business and management area. Rather than searching for each of these terms and variations thereof, this second search focused on business research on additive manufacturing and 3D printing and then analyzed the articles through the business model canvas. The search focused on the following research areas: operations research management science, management, and business (research areas defined by the database).

The second search resulted in 82 journal articles referring to additive manufacturing and 66 journal articles describing 3D printing. Among these, 34 journal articles overlapped, leading to 114 unique publications. In the analysis, these journal articles were combined with the result of the initial search meaning that a total of 116 journal articles were analyzed (thus representing an overlap of four articles between the searches). To verify the search result, complementary searches were performed in the databases Scopus and Business Source Premier. Although these searches captured additional publications, the publications were excluded based on the low ranking of the journals or were news items, and similar (and not journal articles).

The 116 articles were analyzed to figure out what assumptions were made about additive manufacturing/3D printing in relation to companies and their management, how the business/management scholars linked to the technological side of additive manufacturing/3D printing, and whether and how the scholars described a process of change, current business models (or parts of business models), or completely new actors and business models entering into a business sector, thus implying a remodelling also on the industry level. More specifically, the journal articles were classified into whether they concerned key resources, key partners, key activities, the value proposition, customer relationships, customer segments, channels, revenue streams, or cost structures. The changes to these were then discussed in terms of changes to content, structures and governance mechanisms as extracted from the different parts of the business models (Zott & Amit, 2010). Appendices 1, 2 and 3 present the articles reviewed and their classifications and content specifications.

Findings

Frequencies

Figure 2 illustrates the frequencies of journal articles per search term (additive manufacturing, 3D printing, or both combined) and by year. As indicated by the figure, there has been a steep rise in the number of journal articles on additive manufacturing and 3D printing during the past few years. Although the data includes few articles published before 2014, it nonetheless suggests that the frequent use of 3D printing as a keyword is a recent trend.

In terms of the types of journals, most of them have a strong technology/innovation or operations management orientation, with *Journal of Manufacturing Systems* (17 publications), *Journal of Manufacturing Technology Management* (14 publications), *International Journal of Production Research* (10 publications), and *Technological Forecasting and Social Change* (10 publications) dominating. The type of journals is partly reflected in the key research areas, which focus on the way a company's offering is produced (key resources and key activities) rather than the value proposition or sales/customer side of the business model, as discussed below.

Business models in additive manufacturing

As Table 1 reveals, most of the journal articles concern the providing side (key partners, resources, and activities) of the business models (77 journal articles in total), with the main emphasis on key activities (42 articles), seconded by key resources (29 articles). These articles concern such issues as how manufacturing is or should be organized with additive manufacturing, the comparison between traditional and additive manufacturing (Achillas et al., 2015), or descriptions of a specific manufacturing process (Zhao et al., 2017). Additionally, several of these articles only refer to additive manufacturing as one of several technologies affecting the future development of producing firms (Hoover & Lee, 2015; Mortara & Parisot, 2016; Pisano et al., 2015).

As for changes, it is mainly the key activities that are expected to change due to the introduction of additive manufacturing. Mavri (2015), for instance, describes how the production chain changes due to additive manufacturing. Ben-Ner and Siemsen (2017) and Laplume, Petersen, and Pearce (2016b) include the change of supply chains in this regard, describing the shift from global to local, and from long to short supply chains. While not being very specific about the changes of "who does what", articles by Ben-Ner and Siemsen's (2017) and Laplume and colleagues (2016b) indicate a change of governance (cf. Zott & Amit, 2010), whereas Mavri (2015) and most other articles focusing on changes to production concern the change of content (activities pursued; cf. Zott & Amit, 2010). This also means that additive manufacturing would foremost be seen changing internal processes of the firm, also indicated by the quite limited number of articles (six) focusing on key partners. The articles concerning key partners mainly

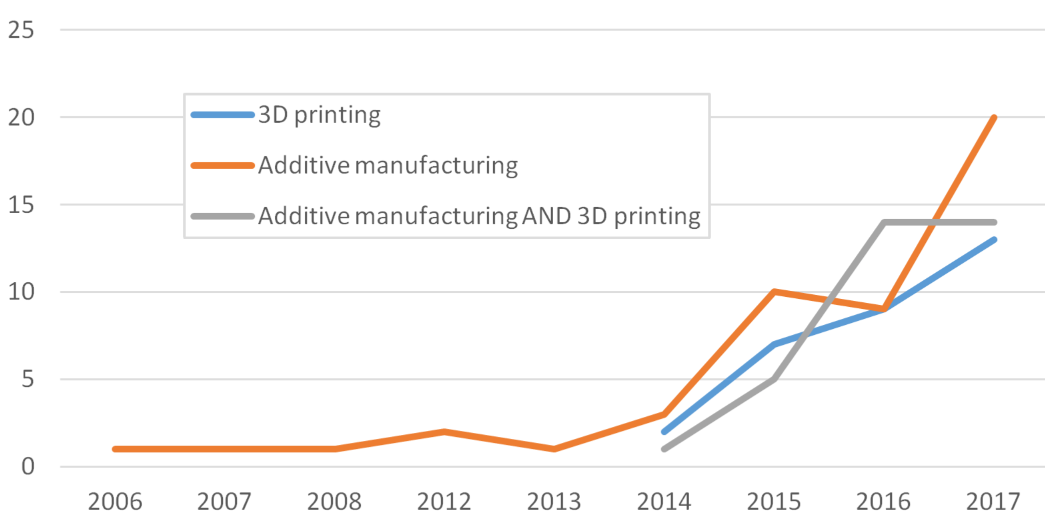

Figure 2. Frequency of results for each search term by year

Table 1. Key themes by year

Theme	2006	2007	2008	2012	2013	2014	2015	2016	2017	Total
Key partners							1	1	4	**6**
Key activities	1		1			4	9	13	14	**42**
Key resources		1		1		2	6	7	12	**29**
Value proposition				1	1		1	4	6	**13**
Customer relationships						1	2			**3**
Cost structure								2	2	**4**
Revenue stream							1			**1**
Policy/societal level							1		3	**4**
Not in focus				1			1	6	6	**14**
Total	**1**	**1**	**1**	**3**	**1**	**7**	**22**	**33**	**47**	**116**

describe platforms or communities for design, examine technology transfers from universities, or emphasize the difficulties for small firms to adopt the technology (Birtchnell et al., 2017; Flath et al., 2017; Samford et al., 2017; West & Kuk, 2016). The limited attention paid to key partners implies that additive manufacturing would not require any major changes to core competences of firms or the companies would be equipped to change their current competences to fit with future needs. Related to this, is an acknowledgement of how additive manufacturing could expect to create disruption for certain companies along the supply chain (Mohr & Khan, 2015).

As for key resources, the discussion in the literature focuses on such issues as intellectual property rights (Gardan & Schneider, 2015; Kurman, 2014; Steenhuis & Pretorius, 2017), manufacturing issues and printer choices (Dwivedi et al., 2018; Elango et al., 2016; Paul & Anand, 2015), skills and (financial) support systems, and how new structures may be produced using additive manufacturing (Gardan & Schneider, 2015; Vongbunyong & Kara, 2017; Zhao et al., 2017). While partly concerning changes to resources (such as new skills or changes to intellectual property rules), most articles on key resources describe quite a static view, also not indicating any changes to content, structures, or governance (Zott & Amit, 2010).

As for the offering, 13 journal articles concern value propositions (cf. Osterwalder & Pigneur, 2010). These include the type of products produced through additive manufacturing: rapid prototyping and innovations, for instance (Berman, 2012; Maric et al., 2016; Rayna & Striukova, 2016; Salles & Gyi, 2013). Rayna and Striukova (2016) make an overview of various offerings and the incremental or radical change they describe, and Laplume and co-authors (2016a) illustrate how small firms use 3D technology in their offerings. Others link additive manufacturing to business performance or business impact more generally (Niaki & Nonino, 2017; Rylands et al., 2016), or describe how incumbent firms would react to the entrance of 3D technology or 3D-printer firms (Hartl & Kort, 2017; Kietzmann et al., 2015). The articles concerning the value propositions broadly defined partly point at changed governance (Zott & Amit, 2010) as new players may enter, but mostly indicate an increased number of practices and thereby offerings enabled through additive manufacturing.

As for the sales side, only three journal articles could be seen to concern customer-related issues, then focusing on customer relationships or changes to them. Rayna, Striukova, and Darlington (2015) discuss co-creation with customers in relation to 3D printing. Christopher and Ryals (2014) introduce the idea of demand chains to emphasize how additive manufacturing means customization and how ideas are pulled by customers rather than created by manufacturers and pushed onto customers. Appleyard (2015), lastly, reflects on piracy music as a means to understand 3D as a process owned by consumers. Thus, the limited literature on the sales side indicates how customers increase their influence and activity on what is produced, thus implying a change in governance of ideas (Zott & Amit, 2010), or "who does what".

The cost structure is discussed in four articles focusing on the analysis of total costs of production or a change in the cost structure with printers being expensive, while the cost of producing low series is less so (Baumers et al., 2016; Baumers et al., 2017; Manogharan et al., 2016; Tsai, 2017). As for revenue streams, Weller, Kleer, and Piller (2015) discuss revenues related to entry barriers and point at how additive manufacturing may lower entrance barriers, thereby impacting competition and revenues.

In addition to those articles that could be linked to any part of the business model, there are a few journal articles focusing on the societal and policy level, along with a total of 14 articles having 3D printing as one of several empirical examples, while not giving the technology or its business impact any focus.

Summary of results

To summarize the findings, most journal articles thus concern the providing side of the business model, often with an internal manufacturing focus. Optimization is discussed either including changes to activities or meaning that 3D printing is a technology used in processes similar to those of traditional manufacturing. Little suggests knowing about changes to structures (cf. Zott & Amit, 2010), whereas key activities are linked to potential activity changes, and key resources are linked more to static descriptions. The discussion on key partners is limited, where supply chain discussions are quite general while not describing partnerships. Notably, the literature seems to imply that the companies in their internal processes are expected to adjust their core competences to new production methods, rather than link these to partnerships. Value propositions describe various offerings enabled through additive manufacturing, focusing on innovations and prototyping mostly, whereas the literature on the sales side/customer-related issues concerns the increased involvement of customers, implying a possible shift in power (cf. Öberg, 2018) to the customers' advantage. Discussions on change in business models or their parts focus on some changes to content (activities) related to production, and some few examples of changes in governance (who does what) in supply-chain structures and the shift to customers' activities, whereas the structures (the links among activities), and thereby the holistic business model influence of additive manufacturing does not seem to be described in previous research. Early articles seemed to be more prescriptive about what would happen, while more recent ones are more questioning to 3D printing/additive manufacturing.

Conclusions

This article summarizes current knowledge on additive manufacturing within management and business research, which leads us now to a discussion of future research directions in relation to business models for additive manufacturing. The literature review indicates a continuous focus on production issues also in the business and management literature. There is an indicated shift from positive connotations to increased questioning of the entrance and meaning of additive manufacturing in the production systems of tomorrow. There is also, when describing how business may change, the tendency to relate to parallel developments in business: the co-production and increased fuzziness between producers and consumers as crowds and communities affect design and production procedures (Ebner et al., 2009; Gulati et al., 2012; von Krogh et al., 2003) that would not be the direct consequence of additive manufacturing.

In terms of business models, what is rarely considered are changes in key partners, entirely new type of offerings, or revenue streams. What is also not considered is how individual companies, given their supply chain position, change or need to change their positions but also competences to meet those challenges and opportunities that additive manufacturing may bring about (Shams & Öberg, 2017). Changes to how various activities are linked are seldom described, which could imply that additive manufacturing is viewed from the lens of traditional manufacturing. And, empirical data beyond measurement in calculations of internal company optimization of manufacturing is rare.

Additive Manufacturing and Business Models: Current Knowledge and Missing Perspectives *Christina Öberg, Tawfiq Shams, and Nader Asnafi*

A research agenda for additive manufacturing and business models

Studies on additive manufacturing and its impact on business models are thus scarce, and there is a need to further explore the area and its many different aspects. Specifically, more empirical work is needed, moving knowledge away from scenarios and into how 3D printing in fact affects current businesses on the company level. The following research streams are suggested:

- *Research on value propositions and customer-related issues.* This would include how offerings are presented, decisions on channels and segments, and their consequences for firm performance. The holistic view including all parts of the business model and how various business models affect the performance of the firm in relation to additive manufacturing would also be important to study, as would the focus on structures (links among activities, cf. Zott & Amit, 2010).

- *Research focusing on how individual firms based on their present roles as manufacturers/suppliers, logistics providers, and business customers would change or need to change their roles so as to fit with additive manufacturing.* Such research would include the study of various companies as units of analysis and how additive manufacturing would lead to new business opportunities, or constrain current ones. Depending on the company's position in the supply chain, the vulnerability to additive manufacturing would differ, and the studies could compare companies based on their various supply-chain positions, while thus focusing on the company level.

- *Research on the effects of parts, tooling, and prototyping.* This would include how companies at various supply chain position would be affected by, take on, and also potentially try to move into more lucrative positions as, for instance, part manufacturing would be insourced by other companies. Comparisons could here be made among companies at each position for the effects of parts, tooling, and prototyping, respectively.

- *Research on what competences are needed as companies adapt to additive manufacturing and depending on the company's current role.* Competences would not only include those of additive manufacturing, but also competences on how offerings could be created, and they may well mean that a company manages to keep its position based on specific competences, while it would otherwise be challenged by the additive manufacturing. Competences should ideally be studied over time to see how requirements of them change, and how companies develop and adjust them. The role of key partners and thereby structures and governance would be important to study in relation to competences.

- *Research into how payment models should be designed to minimize financial risks, while also taking into account the high investments of additive manufacturing.* The payment systems and price strategies of today traditionally focus on how a customer pays the supplier for products delivered. In multiple-party systems, and if competences become a key concern, the way and for what payments are made could expect to change and create new and more creative business models.

- *Research taking a deeper look into customer interaction from the perspective of home-based production.* While it is important to contextualize any development, it is also important to study the customer interaction as an isolated activity (that is, not in conjunction with, for instance, community trends) so as to understand how roles and powers are changed for parts, tooling, and prototyping, respectively.

- *Research into additive manufacturing/3D printing using different materials.* Most studies concern plastic materials, and it would be important to compare how various materials change the business models of companies in similar or different ways. This would include comparing plastics with metal printing, for instance, in how they would cause changes to business models of companies.

Managerial implications

Related to the findings from this article and also the research gaps indicated above, it would be important for any manager introducing additive manufacturing, or challenged by competitors doing so, to grasp how the interaction with customers could expect to change, what additive manufacturing means for cost structures – and thereby risk – but also what competences would be required to successfully operate the new technology. The literature indicates some changes to manufacturing as additive manufacturing is introduced, but in addition to these, it would be important to carefully analyze what activities may be excluded, how this affects the current business and connections to key partners, along with the business performance of the company. Hence, there are several issues to consider, where the present literature gives a good overview of effects on production, but less often links this to the entirety of the company. Through adopting a holistic business model perspective on the introduction of additive manufacturing and its consequences, it is easier to also grasp the coordination of activities (the structures, Zott & Amit, 2010). Furthermore, specific attention should be directed at how additive manufacturing may provide opportunities in terms of new offerings, customer involvement, and customization, along with production-to-order, and how these affect the business model from a provision, offering, sales, and cost/revenue side.

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Appendix 1. Reviewed articles found using the search term "additive manufacturing". Articles are ordered by publication date from newest to oldest. None of the articles included business model as a topic.

Article	Journal	Main Theme	Business Model
Hartl & Kort (2017)	*International Journal of Production Economics*	How incumbent firms react to new market entries of 3D-printing firms	Value proposition
Ambriz et al. (2017)	*Journal of Manufacturing Systems*	Material handling related to 3D	Key activities
Smith & Kerbache (2017)	*Journal of Manufacturing Systems*	Supply chain network design. Additive manufacturing (AM) as deconstructing supply chains	Not in focus
Samford et al. (2017)	*Business and Politics*	High costs of AM leading to difficulties for small firms to adopt the technology; how can they be supported	Key partners
Attaran (2017)	*Business Horizons*	AM implementation challenges and opportunities; changes to production	Key activities; offering
Roca et al. (2017)	*Research Policy*	Regulation of emerging technologies	Not in focus
Jin et al. (2017)	*Journal of Manufacturing Systems*	Process planning of AM	Key activities
Sturm et al. (2017)	*Journal of Manufacturing Systems*	Cyberattacks to AM processes	Key resources
Le et al. (2017)	*Journal of Manufacturing Systems*	The combined use of additive and subtractive manufacturing	Key resources
Ransikarbum et al. (2017)	*Journal of Manufacturing Systems*	A decision-aiding model to coordinate multiple printers. Parts. How different printers are needed and should be coordinated for optimization (operations).	Key resources
Giberti et al. (2017)	*Journal of Manufacturing Systems*	Original path planning algorithm including AM. Production processes (operations).	Key activities
Zhao & Rosen (2017)	*Journal of Manufacturing Systems*	Approach of interferometric curing monitoring and measuring data mining to intelligently decipher part height. Parts. Focus on production processes (operations).	Key activities
Roca et al. (2017)	*MIT Sloan Management Review*	Over-optimism in 3D printing. View on 3D and its potential influences.	Policy/societal level
Baumers et al. (2017)	*International Journal of Production Research*	Comparison of costs between AM and traditional manufacturing, also including changes to production processes	Cost structure
Strange & Zucchella (2017)	*Multinational Business Review*	New technologies (web 4.0) affecting location of firms	Not in focus
Jin et al. (2017)	*International Journal of Computer Integrated Manufacturing*	Extrusion-based layered deposition as an AM technology	Key resources
Vongbunyong & Kara (2017)	*International Journal of Computer Integrated Manufacturing*	Cellular structure enabled through AM. Focus on the manufacturing.	Key resources
Niaki & Nonino (2017)	*Journal of Manufacturing Technology Management*	Impact of AM on business performance	Value proposition
Aboutaleb et al. (2017)	*IIE Transactions*	Optimizing processes from a cost and time perspective. Parts. Manufacturing (operations).	Key activities
Li et al. (2017)	*International Journal of Production Research*	The impact of AM on spare parts supply chain. Simulations. Parts. Supply chain.	Key activities
Popescu et al. (2016)	*Studies in Informatics and Control*	Communities/platforms in orthopedic applications	Not in focus
Portoles et al. (2016)	*Journal of Manufacturing Systems*	Quality assurance in AM for aero industry. Parts, metallic. Manufacturing.	Key activities
Chen & Xiao (2016)	*Systems & Control Letters*	Disturbances in production	Not in focus

Appendix 1. ***(continued)*** Reviewed articles found using the search term "additive manufacturing". Articles are ordered by publication date from newest to oldest. None of the articles included business model as a topic.

Article	Journal	Main Theme	Business Model
Manogharan et al. (2016)	*International Journal of Computer Integrated Manufacturing*	Economic models (cost side) of additive and subtractive methods. Manufacturing and cost-side.	Cost structure
Paz et al. (2016)	*International Journal of Computer Integrated Manufacturing*	Optimized design of parts (e.g., different structures of material). Parts. Manufacturing.	Key activities
Featherston et al. (2016)	*Technovation*	New technologies	Not in focus
Wagner & Walton (2016)	*Production Planning & Control*	The current and future states of AM in the aviation industry. Supply chain. Parts.	Key resources
Bastani et al. (2016)	*IIE Transactions*	AM as an empirical example to test online sparse estimation-based classification.	Not in focus
Caputo et al. (2016)	*Business Process Management Journal*	Internet of Things framework tested on AM.	Not in focus
Xu et al. (2015)	*International Journal of Production Research*	A method to build an energy consumption model for printing stage of binder-jetting processes	Key activities
Gartner et al. (2015)	*Creativity and Innovation Management*	The need for policies about AM	Policy/societal level
Kim et al. (2015)	*Concurrent Engineering-Research and Applications*	AM process example to illustrate processes in smart manufacturing environments	Key activities
Mohr & Khan (2015)	*Technology Innovation Management Review*	The areas of the supply chain most likely to be disrupted by 3D printing technology	Key activities
Ali & Rehman (2015)	*Journal of Manufacturing Systems*	Novel manufacturing methods in medicine	Key activities
Gardan & Schneider (2015)	*Journal of Manufacturing Systems*	How what is manufactured is allowed to change (complex geometrics) by means of AM	Key resources
Paul & Anand (2015)	*Journal of Manufacturing Systems*	Analysis of form errors	Key resources
Eyers & Potter (2015)	*Journal of Manufacturing Technology Management*	The use of e-channels for files between designer and manufacturer in AM	Key resources
Appleyard (2015)	*Business Horizons*	The development of the music industry (piracy) as example to understand AM as a production process owned by consumers	Customer relationships
Toth et al. (2015)	*Quality Innovation Prosperity*	The use of 3D for customized implant manufacturing	Key resources
Liu et al. (2014)	*Production Planning & Control*	The impact of AM in the aircraft spare parts supply chain. Scenarios including distributed and centralized supply chains.	Key activities
Christopher & Ryals (2014)	*Journal of Business Logistics*	From supply chain to demand chain. AM as one of the clues for this.	Customer relationships
Mellor et al. (2014)	*International Journal of Production Economics*	Implementation framework for AM	Key activities
Salles & Gyi (2013)	*International Journal of Computer Integrated Manufacturing*	The production of personalized footwear through AM	Value proposition
Paul & Anand (2012)	*Journal of Manufacturing Systems*	Energy calculations for laser sintering	Key resources
Berman (2012)	*Business Horizons*	3D as a revolution. Current practices mostly prototyping though	Value proposition
Ren et al. (2008)	*Journal of Manufacturing Systems*	Process planning of AM of metals testing various techniques	Key activities
Bingham et al. (2007)	*International Journal of Computer Integrated Manufacturing*	Rapid manufacturing in textile through AM. Technological focus.	Key resources
Ram et al. (2006)	*Journal of Manufacturing Systems*	Layer-based 3D printing in metals. Technology in focus.	Key activities

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Appendix 2. Reviewed articles found using the search term "3D printing". Articles are ordered by publication date from newest to oldest. Articles in bold include business model as a topic.

Article	Journal	Main Theme	Business Model
Flath et al. (2017)	*Journal of Information Technology*	Platforms for 3D design	Key partners
Rindfleisch et al. (2017)	*Journal of Product Innovation Management*	Innovation as data, 3D as example	Not in focus
Dotsika & Watkins (2017)	*Technological Forecasting and Social Change*	3D as one of several disruptive technologies. Focus on methods to discover disruptive technologies.	Not in focus
Hartmann & Vanpoucke (2017)	*Journal of Organizational and End User Computing*	Customer acceptance with 3D as an example (intention to use)	Value proposition
Zhang et al. (2017)	*Journal of Manufacturing Systems*	Manufacturability optimization in processes including 3D and traditional manufacturing. Production processes (operations).	Key activities
Kyriakou et al. (2017)	*MIS Quarterly*	The reuse of 3D models. Customization and supply-side in communities.	Key partners; customer relationships
Walsh et al. (2017)	*Small Enterprise Research*	How 3D platforms support small firms in their innovation and commercialization processes	Key resources
Tsai (2017)	*International Journal of Production Research*	The impact of cost structure on cash flow risk; AM as one example	Cost structure
Wu et al. (2017)	*Journal of Manufacturing Technology Management*	Risks in projects	Not in focus
Zhao et al. (2017)	*International Journal of Computer Integrated Manufacturing*	Truss structures enabled through 3D printing	Key resources
Bai et al. (2017)	*Journal of Manufacturing Technology Management*	Comparative advantage of 3D printing among countries	Value proposition
Long et al. (2017)	*International Journal of Production Research*	The impact of 3D on Chinese manufacturing	Key activities
Schniederjans (2017)	*International Journal of Production Economics*	Adoption of 3D technology among top managers.	Key activities
Stanko (2016)	*Information Systems Research*	Online communities	Not in focus
Kannattukunnel (2016)	*International Journal of Innovation and Technology Management*	Patents and investments in 3D. Technology/manufacturing.	Key activities
Laplume et al. (2016a)	*International Journal of Advanced Manufacturing Technology*	The use of 3D printing for small manufacturing firms in their offerings	Value proposition
Kothman & Faber (2016)	*Journal of Manufacturing Technology Management*	Impact of AM on performance: efficient manufacturing and changed supply chain structure	Key activities
Maric et al. (2016)	*Journal of Innovation Economics & Management*	Frugal innovation	Value proposition

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Appendix 2. ***(continued)*** Reviewed articles found using the search term "3D printing". Articles are ordered by publication date from newest to oldest. Articles in bold include business model as a topic.

Article	Journal	Main Theme	Business Model
Elango et al. (2016)	*International Journal of Production Research*	Technology of 3D printers. Technology (manufacturing).	Key resources
Wang et al. (2016)	*International Journal of Production Research*	Chinese consumers' adaption of 3D for home-based manufacturing.	Key resources
Sasson & Johnson (2016)	*International Journal of Physical Distribution & Logistics Management*	Direct digital manufacturing coexisting with traditional manufacturing methods. (Supply chain changes).	Key activities
West & Kuk (2016)	*Technological Forecasting and Social Change*	Openness in 3D printing. Manufacturing (community-based, that is, its organizing)	Key partners
Rayna & Striukova (2016)	*Technological Forecasting and Social Change*	3D printing affecting business models	Value proposition
Hull (2015)	*Research-Technology Management*	Development, descriptive	Key resources
Han & Sohn (2015)	*Journal of Technology Transfer*	Patents. 3D as empirics.	Not in focus
Pisano et al. (2015)	*Entrepreneurship Research Journal*	Business models as a means to better react to new trends. 3D as one example.	Key activities
Rayna et al. (2015)	*Journal of Engineering and Technology Management*	Online 3D printing and its effect for co-creation	Customer relationships
Huang et al. (2015)	*IIE Transactions*	Shape shrinkage in manufacturing with 3D	Key resources
Rayna & Striukova (2015)	*International Journal of Technology Management*	Challenges of co-creation. 3D as one example.	Key partners
Mavri (2015)	*Knowledge and Process Management*	Change in production chain due to AM	Key activities
Potstada & Zybura (2014)	*Technological Forecasting and Social Change*	Home printing for consumers	Key activities
Fawcett & Waller (2014)	*Journal of Business Logistics*	Adaptation and proactiveness	Key activities
Zeleny (2012)	*International Journal of Information Technology & Decision Making*	Barriers to innovation. 3D mentioned as one technology affecting innovation and changing customers' role.	Not in focus

Additive Manufacturing and Business Models: Current Knowledge and Missing Perspectives *Christina Öberg, Tawfiq Shams, and Nader Asnafi*

Appendix 3. Reviewed articles found using the search terms “additive manufacturing” AND “3D printing”. Articles are ordered by publication date from newest to oldest. Articles in bold include business model as a topic.

Article	Journal	Main Theme	Business Model
Ben-Ner & Siemsen (2017)	*California Management Review*	Changes to production: from global to local; from mega to mini; from long to short supply chains	Key activities
Birtchnell et al. (2017)	*Technological Forecasting and Social Change*	The role of universities in the development of 3D printing knowledge	Key partners
Li et al. (2017)	*Computers & Operations Research*	Cost functions of AM. Very different cost structures to traditional manufacturing.	Key resources
Jiang et al. (2017)	*Technological Forecasting and Social Change*	Scenarios on future development (2030) through Delphi methods	Policy/societal level
Trappey et al. (2017)	*Technology Analysis & Strategic Management*	Patent analysis approach to explore biomedical 3D printing technology trends. Technology.	Key resources
Despeisse et al. (2017)	*Technological Forecasting and Social Change*	Whether or not 3D will lead to sustainability, and how it need to function to do so. How 3D affects – positively and negatively – the development of a circular economy.	Policy/societal level
Durach et al. (2017)	*International Journal of Physical Distribution & Logistics Management*	AM processes, their barriers and impact on supply chains	Key activities (supply chain)
Dwivedi et al. (2017)	*International Journal of Physical Distribution & Logistics Management*	Barriers to AM in Indian car industry; technological skills and governmental support as main issues	Key resources
Ryan et al. (2017)	*International Journal of Physical Distribution & Logistics Management*	Scenarios for 3D printing. Supply chain.	Key activities
Achillas et al. (2017)	*International Journal of Production Research*	Different AM technologies are compared in terms of lead time and total production cost with injection molding	Key activities
Gibson (2017)	*Journal of Manufacturing Technology Management*	State of the art in 3D printing related to business. Changed applications over time.	Value proposition
Holzmann et al. (2017)	*Journal of Manufacturing Technology Management*	User entrepreneur business models in 3D printing	Value proposition
Deradjat & Minshall (2017)	*Journal of Manufacturing Technology Management*	Dental sector; implementation of 3D for mass customization. Focus on technology.	Key resources
Steenhuis & Pretorius (2017)	*Journal of Manufacturing Technology Management*	AM innovations. Focus on issue of IP among others.	Key resources
Laplume et al. (2016b)	*Journal of International Business Studies*	Ideas (about the future) and how 3D may impact global supply chains. Increased geographically dispersion and production closer to the end users (localization). Changes to supply chain. Future oriented.	Key activities
Holmstrom et al. (2016)	*Operations Management Research*	Discussion of current over-optimism for 3D and how it in the future may change supply chains, etc., but not yet indicates the major shift and advantage to current production methods. Supply chain.	Key activities
Gardan (2016)	*International Journal of Production Research*	Review of the different AM technologies and the new trends. Focus on technology and manufacturing. Technology/manufacturing process	Key activities
Meisel et al. (2016)	*Journal of Manufacturing Technology Management*	Decision support for AM; focus on resources	Key resources

Appendix 3. ***(continued)*** Reviewed articles found using the search terms "additive manufacturing" AND "3D printing". Articles are ordered by publication date from newest to oldest. Articles in bold include business model as a topic.

Article	Journal	Main Theme	Business Model
Knofius et al. (2016)	*Journal of Manufacturing Technology Management*	Spare parts through AM in logistics	Key resources
Oettmeier & Hofmann (2016)	*Journal of Manufacturing Technology Management*	Impact of AM on supply chain components and processes. Hearing industry.	Key activities
Rylands et al. (2016)	*Journal of Manufacturing Technology Management*	Adaptation of AM in manufacturing and its business impact	Value proposition
Steenhuis & Pretorius (2016)	*Journal of Manufacturing Technology Management*	Consumer AM impact on future manufacturing industry	Key resources
Rogers et al. (2016)	*International Journal of Physical Distribution & Logistics Management*	3D services and their impact on supply chains. Literature review and research agenda. Services (external parties' provision). Supply chain.	Key activities
Mortara & Parisot (2016)	*International Journal of Production Research*	AM as one of several production techniques at fab-spaces (not key focus). Manufacturing. Organizing of manufacturing.	Key activities
Salvador & de Menendez (2016)	*Journal of Intelligence Studies in Business,*	The potential effect of bio-additive manufacturing on healthcare	Key activities
Sandstrom (2016)	*Technological Forecasting and Social Change*	How AM has been adopted for manufacturing and its potential impact competition in different industries. Hearing aid case study. Technology and new manufacturing possibilities.	Key resources
Baumers et al. (2016)	*Technological Forecasting and Social Change*	Cost performance using two different techniques	Cost structure
Bogers et al. (2016)	*Technological Forecasting and Social Change*	The implications of AM on production systems in new business models. Focus on consumer goods and open business models implying a consumer-centric logic and changes to supply chains.	Key activities
Hoover & Lee (2015)	*Research-Technology Management*	3D as one force of change in the current business landscape (in parallel with, e.g., sharing)	Key activities
Achillas et al. (2015)	*Journal of Manufacturing Systems*	A decision-making framework for selecting an effective portfolio of production strategies, including alternative additive and traditional manufacturing technologies. AM effective for small series and high customization (increased supply chain responsiveness). Injection molds to traditional manufacturing also in larger series.	Key activities
Weller et al. (2015)	*International Journal of Production Economics*	The impact of AM on firm and industry level from an operational management perspective. In monopoly situation, firms may increase their revenues, while in competitive markets, AM lowers entrance barriers	Revenue stream
Kietzmann et al. (2015)	*Business Horizons*	The impact of AM on firms and consumers	Value proposition
Tatham et al. (2015)	*Journal of Humanitarian Logistics and Supply Chain Management*	The use of 3D in disaster and development activities	Key activities
Kurfess & Cass (2014)	*Research-Technology Management*	Intellectual property changes as a result of AM	Key resources
Kurman (2014)	*3D Printing and Additive Manufacturing*	Intellectual property as inefficient in AM	Key resources

From Organizations to Organizational Fields: The Evolution of Civic Innovation Ecosystems

Matthew Claudel

> *The things we fear most in organizations – fluctuations, disturbances, imbalances – are the primary sources of creativity.*
>
> Margaret J. Wheatley
> Author, speaker, and management consultant

Contemporary approaches to urban technology emphasize local "innovation ecosystems". Two organizational models – living labs and innovation integrators – are commonly used as hubs to broker these ecosystems. Curiously, both coexist in some cities, allowing a comparison of their impact and an analysis of their development over time and in context. The case studies presented in this article suggest that our analytical frameworks for technology policy may fall short, in that they contemplate only the organizations themselves – the living labs or innovation integrators. The dynamics observed in each city are well articulated, however, in the sociotechnical systems literature. The hub can be understood as a "niche", which fosters radical innovations and new processes. As these prototypes are increasingly deployed and accepted, there is a regime shift, ultimately creating an experimentalist culture that fills the role previously held by the hub. This conclusion is neither a challenge to ecosystem theory nor a critique of innovation policy and its implementation. Rather, I suggest that we must extend these theoretical frameworks, drawing on sociotechnical systems literature to better account for institutions and for systems change as we design policy for urban technology. This article therefore makes a contribution by using a sociotechnical systems lens to explain the evolution of local urban innovation ecosystems.

Introduction

Urban technology is a growing area of economic, social, and political opportunity, but the appropriate model for creating it remains a debate in both academia and practice. We are now many years into the urban technology movement – the ideas of smart cities, living labs, urban technology, e-government, etc. have become familiar. The contemporary innovation ecosystem approach emphasizes the need for a "hub" organization that coordinates local stakeholders (for example, by facilitating idea-transfer into and out of city government, translating between technologists and non-profits, hosting prototyping facilities, or pooling funds). Two main hub models have emerged in recent years – living labs and innovation integrators. This article evaluates the operations of these two organization models, and their dynamic change over time, using a unique case design: cities where both co-exist.

At this stage in the history of urban technology policy, it is important to understand the success of various approaches, as they have been deployed in real cities and matured over time. To that end, this article presents an analysis of eight organizations: four living labs and four innovation integrators in four different cities. Using semi-structured interviews with stakeholders inside and outside the organizations, I characterize the structure, typical projects, and outcomes of each organization. From this analysis, I draw three primary conclusions. First, living labs and innovation integrators have evolved since their founding, following one of three paths: they specialize, split into multiple entities, or shift to a mediating role. This is not a failure of the organizations, but rather a result of a change in the surrounding urban context. As the ecosystem becomes more familiar with urban technology, there is less need for a "hub", and the organizations are free to specialize to their strengths. Developing urban technology is no longer the responsibility of a single hub organization, but is now a collaborative goal shared by multiple actors, project by project. Second, city governments are successfully working with their local ecosystems independently, rather than procuring urban technology from large IT firms or relying on a central innovation hub (the ecosystem hub approach). Finally, several specific barriers to urban technology (such as access to resources, networking, and testing in public space), which were initially lowered by living labs and innovation integrators, are now mitigated by cross-sector networks, shared culture, and mutual trust. It is difficult to frame the observed evolution of living labs and innovation integrators purely within the theoretical framework of urban technology systems. However, by considering the city as a sociotechnical system – beyond a narrow analysis of the organizations themselves – it becomes clear that the hubs' early projects created conditions for a more open, distributed mode of working among various stakeholders.

Innovation Ecosystems and Hub Organizations

The original computing- and efficiency-oriented vision of smart cities has been redirected (Stratigea et al., 2015). A contemporary approach to urban technology directly addresses many of the critiques of the smart city (Curley, 2016), now accounting for non-economic, non-technological outcomes, and spanning sectors: public, private, academic, and citizen (Vanolo, 2014). In this "innovation ecosystem" framework, the definition and development of projects both involve many and varied stakeholders (Snow et al., 2016). Proponents have argued that this can improve outcomes, for example, by revealing local conditions during problem definition, leveraging community expertise during project development, or accounting for livelihoods as the result is integrated (Desouza & Bhagwatwar, 2012; Voss & Carolan, 2012). This is because urban technology is uniquely concerned with the supply side (participation, innovation) and the demand side (use, integration), in that it links local actors, institutions, and places in the fulfilment of societal functions (Cohen et al., 2016; Kontokosta, 2016). Independent of technological or economic outcomes, the innovation process itself can generate collective social benefit through empowerment, equity of access, and capacity-building (Booher & Innes, 2002; Gerometta et al., 2005; Shin & Shin, 2016).

Consider Amsterdam's Biogas Boat as an example of the urban innovation ecosystem approach (Table 1). The Biogas Boat is a floating, mobile restaurant that converts organic waste into fertilizer and biogas, which it then uses for cooking meals. The project involved five different supporting partners, crowdfunding, academic research facilities, a diverse project team, and a unique set of urban assets, including Amsterdam's canals, disused boats, and a post-industrial site.

Table 1. Urban waste innovation in Amsterdam

Dimension	Description
Technology	Biogas Boat
Finance	• Crowdfunding: €10,000 • Municipality €10,000 • Foundation: €30,000 • Research funds: €10,000 • *Total: €60,000*
Brief	"In the Biogas Boat, we are building a biodigester that converts all the organic waste produced at De Ceuvel [Café] into biogas, which can be used to cook with. ... In the near future, she will visit festivals to collect organic matter to convert into gas and fuel, thereby showing a larger audience the great potential of waste." (Biogas Boat, 2018)
Project Team	• Simme Andriesma (Entrepreneur/Designer) • Rolf Steenwinkel (Amsterdam Energie) • Enki Energy Company (Technology Specialist) • Huib Koel (Boat Designer)
Project Partners	• City of Amsterdam • Stichting DOEN Foundation • Triodos Foundation • BAM Construction • Amsterdam University of Applied Sciences (HvA)
Deployment	One boat at De Ceuvel Café
Challenges	*"We are still waiting for the permit to be issued for the project, before putting everything together. The permit process has been very complicated, and we are still not completely sure whether we will get it."* (Project team member)
Outcomes	*"Our main aim is to carry out this first experiment and make it work on De Ceuvel. The aim is to inspire people to see what can be done with our waste locally. Secondly, we will share the lessons we learned from the project with, for example, the local water authority. They will be able to use these lessons for local bio-digestion projects on a neighbourhood scale."* (Co-founder of Café de Ceuvel)

Contrary to traditional R&D, the urban innovation ecosystem process is inherently ad hoc, shaped by local challenges, resources, and stakeholders (Cooke, 2016; Gascó, 2016). This presents two primary challenges. The first is aggregating the necessary tools and resources, including funding, hardware prototyping facilities, collaborators, data for benchmarking, or regulatory approval to deploy prototypes (Leminen et al., 2012; Schaffers & Turkama, 2012). The second, closely related, challenge is effective collaboration across stakeholder groups, each with distinct "languages" (Bakici et al., 2013; Wareham & Almirall, 2011). For example, a policy maker and a data scientist may not share a mental model for traffic systems, despite both working on autonomous cars. Cross-sectoral innovation therefore requires translation. Biogas Boat merged traditionally siloed sectors: academia (organic waste processing technology), De Ceuvel Café (restaurant operations), government (waste management regulation), in addition to the core team (experts in energy systems, design entrepreneurship, and boat design) and the public, through a crowdfunding campaign and volunteer build-teams. This project demonstrates the social and recombinant nature of innovation: it is the result of local networks (Schumacher & Feurstein, 2007).

Many academics have contemplated the structure of innovation networks and have examined the role of "innovation intermediaries", which translate projects from collaborative exploration to innovative exploitation (Cooke, 2008; Leminen et al., 2012; Nilsson & Sia-ljungström, 2013; Wareham & Almirall, 2011). These intermediaries perform aggregation and mediation functions: they consolidate resources (financial, technological, and talent), and translate between knowledge bases (through convening, consultancy, and best practice). Specific to urban technology, two general models have emerged to fill the hub role: *living labs* and *innovation integrators* (Bakici et al., 2013; Foster & Iaione, 2016). Municipal policy makers seeking to create an urban innovation ecosystem launch such an organization (Gascó, 2016; Juujarvi & Lund, 2016).

Living labs have origins in academia and industry, while innovation integrators began as brokers of civic technology in city governments, such as e-government platforms, IT infrastructure, and smart sensors (see the next section for a short history of the two organization types). Yet both share the hub organizational model (Figure 1). They support initial ideation, or, "exploration" – as both entirely new projects and the recombination of existing resources – and support subsequent implementation or "exploitation" (Cooke, 2008, 2016; March, 1991). Many offer an area for experimentation or actively organize programs and innovation challenges. By engaging their contexts, and publicly demonstrating examples of civic technology, these organizations "perform context-based experimentation in order to generate new socially negotiated meanings for products and services" (Wareham & Almirall, 2011). The surrounding ecosystem is then defined by this central actor. "According to the literature, the ecosystem structure is determined by the position and the role that the 'ecosystem hub' – or the individual organization that directs the ecosystem – plays" (Visnjic et al., 2016).

Living Labs and Innovation Integrators

Building on a longer history in academia, the contemporary manifestation of the living lab concept was articulated by William J. Mitchell, Kent Larson, and Alex (Sandy) Pentland at the Massachusetts Institute of Technology (MIT) in the early 2000s. According to its website (livinglabs.mit.edu): "MIT Living Labs brings together interdisciplinary experts to develop, deploy, and test – in actual living environments – new technologies and strategies for design that respond to this changing

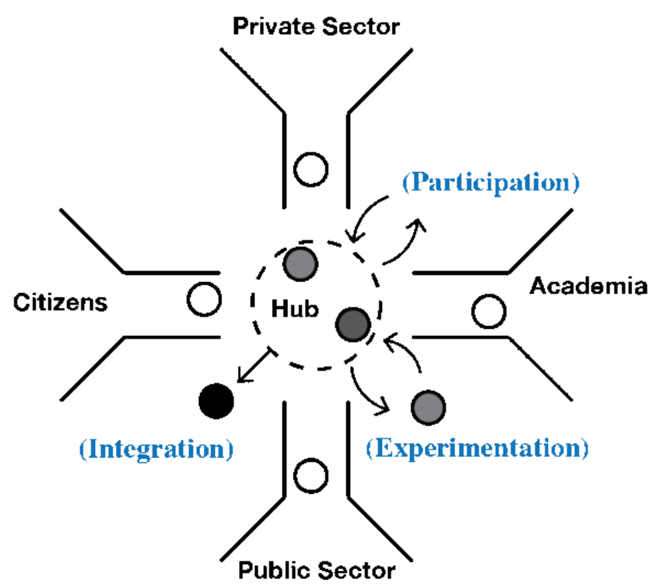

Figure 1. The Innovation Ecosystem Hub Model. The hub centralizes innovation activity by aggregating resources and brokering between different sectors. Circles indicate projects at various levels of completion: participatory problem definition; experimental project development; and integrative product deployment. Figure adapted from Curley and Salmelin (2013) and Visnjic and co-authors (2016).

world. Our work spans in scale from the personal to the urban, and addresses challenges related to health, energy, and creativity."

Subsequent implementation happened primarily in Europe, where living labs gained significant political legitimacy in 2006 from the Finnish Presidency. The *Helsinki Manifesto* (Finland's EU Presidency, 2006) called for "a new European R&D and innovation system", and framed living labs as a crucial "paradigm shift for the whole innovation process". The statement was endorsed by the European Union (EU) and, in the same year, existing organizations were formally linked through the EU-sponsored European Network of Living Labs (ENoLL; enoll.org). One of the primary purposes of the network was to systematize the many organizations – which had quickly become heterogeneous in structure and practice (Mulder et al., 2008) – around a common set of principles. A concomitant report from the European Commission defined the living lab as "a user-driven open innovation ecosystem based on a business–citizen–government partnership that enables users to take an active part in the research, development and innovation process for new services, products and societal infrastructures" (Peltomaki, 2008). The model is based on testing in real-world environments, citizen engagement, and linking stakeholders – as enumerated in the original report. "Involving all relevant players of the value network via partnerships between business, citizens, and government… Allowing for early assessment of the socio-economic implications of new technological solutions by demonstrating the validity of innovative services and business models" (Peltomaki, 2008). For the purposes of this article, I consider labs that are recognized as at least "Adherent Members" of ENoLL, which is its most open membership class.

The *innovation integrator* is equally active, but less cohesively defined. It is more directly associated with municipal governments, often beginning as either a "change unit" or a technology group. These brokering organizations span into and out of city hall, bridging a gap between technical capacity and practical deployment opportunities. Bakici and colleagues (2013) describe them as autonomous "public innovation intermediaries" that work in close partnership with businesses, academia, government, and citizens. "[The] role of public innovation intermediaries is to build networks of organizations and then be the first to attract all the project ideas from these networks… In general, city halls provide financing and incentives for projects and/or legislative support, such as offering opportunities for experimentation" (Bakici et al., 2013). A number of case studies have documented the practices of these intermediaries, for example, how Boston Mayor's Office of New Urban Mechanics pioneered the integration of digital systems into government (Crawford & Walters, 2013) and how Forum Virium in Helsinki sparked ideation for civic problems through open data, hackathons, crowdsourcing, and public innovation contests (Almirall et al., 2014). These innovation integrator organizations experiment with new technologies, through maintaining a local network of actors, directly engaging with citizens, and co-developing with citizens and with firms.

Case Design with Co-Existing Organizations

Hundreds of living labs and innovation integrators are in operation around the world, and a critical evaluation is needed to understand their impact on urban innovation ecosystems. Conceptual and semantic ambiguity has frustrated research on place-based, but technologically agnostic, "territorial innovation systems" (Moulaert & Sekia, 2003). Research focused on specifically urban technology has examined the practices and effectiveness of living labs and innovation integrators independently (Cohen et al., 2016), but none has compared the two. Overarching surveys of the urban technology field have mapped academic disciplines, practical methods, and trends in the discourse (Brynskov et al., 2014).

Comparative research remains vexed. On one hand, analysis of a single organization, or the innovation dynamics of a single city, can provide thorough information (e.g., Juujarvi & Lund, 2016; Scholl & Kemp, 2016; Snow et al., 2016), but insights are difficult to generalize. On the other hand, comparisons of the same organization type across cities can lead to more general conclusions (e.g., Gascó, 2016; Bakici et al., 2013), but must address the problem of comparability across unique contexts, and more importantly, against the other organization type. Broadly speaking, this is the challenge of applying heuristic tools to cities – a well-recognized wicked problem for urban science (Webber & Rittel, 1973). To overcome these hurdles, I both exploit and investigate the phenomenon of co-existence, allowing us to observe how each organization type contends with the same set of local conditions. The central question of this article therefore becomes a useful analytical tool.

The panel of nested cases (Table 2) is further structured to disentangle factors that are specific to each city and those that are shared among cities (Flyvbjerg, 2006; Yin, 2013). This approach bridges the depth of small case

Table 2. Nested cases and interviewees (LL = living lab; ii = innovation integrator)

City & Organization	Interviewee	Title
Aarhus (Denmark)	Line Gerstrand Knive	Office of the Mayor, Aarhus Municipality; Co-founder, Smart Aarhus
	Mads Peter Laursen	Godsbanen, Founder, Director
	Michael Troelsen	Urban Innovation, Office of Environment & Technology, Aarhus Municipality, Director
LL: Digital Urban Living Labs (DULL)	Jesper Algren	Head of Central Denmark Regions ICT
	Martin Brynskov	Professor, Aarhus University; Chair, DK Smart City
ii: ITK Lab	Bo Fristed	Founder and Director, ITK; Aarhus CIO
	Anne Vest Hansen	Head of ITK Lab
	Louise Overgaard	Development Consultant, ITK
	Dennis Borup Jakobsen	Project Manager, ITK
Amsterdam (Netherlands)	Ger Baron	Chief Technology Officer, City of Amsterdam
LL: Urban Management Field Lab	Willem van Winden	Professor, University of Applied Sciences Amsterdam Board Member, Urban Lab
	Robert van den Hoed	Professor, University of Applied Sciences Amsterdam
ii: Amsterdam Smart City	Maaike Osieck	Head of Communications & Engagement
	Vivienne Bolsius	Business Development Manager
Barcelona (Spain)	Gerardo Pisarello Prados	Deputy Mayor, Barcelona
LL: i2Cat	Josep Paradells Aspas	Director, i2Cat
ii: Barcelona Digital City	Joan Batlle Montserrat	Asst. Director, Dept. Creativity & Innovation
	Anna Majo	Digital Innovation Technical Director, Barcelona City Council
Copenhagen (Denmark)	Morten Kabell	Mayor for Environment & Tech, Copenhagen
LL: National Green Lab for Lighting & Smart Urban Technologies (DOLL)	Kim Boström	Head and CTO of DOLL; CTO Gate 21
	Teddy Larson	Senior Project Manager, DOLL
ii: Copenhagen Solutions Lab	Marius Sylvestersen	Program Manager, Copenhagen Solutions Lab

studies with the breadth of larger surveys (Storper et al., 2015). The cities are comparable along factors of the analytical logic: for example, cities host all stakeholder types (including university and large industry), and each has an open data platform and embedded digital infrastructure (enabling various forms of experimentation and participation).

Conversely, variation between cities – across specific factors that relate to the analytical logic – ensures that no single variable is independently responsible for the observed outcomes. Given the focus of this study, the factors that could potentially influence innovation dynamics are:

- *Population:* this factor defines the local market size and attractiveness to international businesses.

- *Political status as a capital:* this factor may impact a city's access to national or international funding for public projects.

- *Nation* (regulation and trade, economy-type, language, education system, etc.): this factor may define innovation activity as well as scale-up opportunities – the panel therefore includes cities within the same country, and cities across different countries).

- *City government* (how long the administration has been in office) *and structure* (e.g., a "strong-mayor system" versus a council system): these factors dictate the creation, communication, and realization of a civic vision.

Analysis

Organization-level evaluation of eight cases

I first examined each organization individually, using interviews with leadership, site visits, and basic data. The analysis considered:

- Organizational structure (internal staff and organization; external partnerships)

- Primary mode of operations (what specific actions the organization carries out)

- Key projects (most prominent or typical project of the organization)

- Outcomes and development (results, sustainability, and evolution over time)

Table 3 briefly characterizes the structure and operational model of each organization. Furthermore, it lists two projects from each organization that typify its work and gives a broad overview of each organization's development over time.

In these eight cases, no organization successfully and sustainably performs as a hub to the ecosystem. Over time, these eight organizations have followed one of three trajectories:

1. *Specialize:* focus operations to achieve a targeted outcome
   (3 cases: UM Field Labs, DOLL, i2Cat)

2. *Split:* multiple sub-organizations or project tracks each specialize
   (3 cases: CPH Solutions Lab / Street Lab, ITK Lab / Street Lab, BCN's urban test site)

3. *Move to a mediating role:* assume a more abstract platform role
   (2 cases: AMS Smart City, DULL becomes Smart Aarhus)

1. Specialize: focus operations to achieve a targeted outcome

Financial constraints have pushed i2Cat to specialize and focus on industry contracts: "now most of our projects are for companies. They want to keep the IP… We can develop solutions and sell you this knowledge" (Josep Paradells Aspas). Specialization has eclipsed the living lab approach itself, to the point that "the living lab methodology is not applied to all projects. In some cases, the company has clear ideas about what they want. They know how to validate the success."

Similarly, DOLL "is a marketplace for procurement. Our goals are: 1. Help public decision-makers with a business case and evidence in a non-mature market, so they can do intelligent spending; 2. Help industry test integration and start making solutions with [new] technology. There is a big business opportunity" (Kim Bostrøm). DOLL's tests inform technology development (e.g., engineering specifications) but are not a vehicle for user feedback. Currently, "we don't have a way of collecting what they think about it. In the future, we imagine user focus groups." Though DOLL provides infrastructure for testing, it is not involved with ideation or technology itself – rather, the leadership frames DOLL as "an open-air catalogue" with a strong model for industry and municipal membership.

Table 3. The eight organizations – four living labs and four innovation integrators – and their host cities

Organization	Structure	Operations	Projects	Outcomes and Development
UM FieldLab Amsterdam	HvA partners with communities, businesses and gov. to find local challenges, and apply solutions	Co-creation, academic research, and neighbourhood application of social science	Youth & Debt Climate Street	Mixed outcomes, generally projects have limited scale (only academic, or application at neighbourhood-scale); now doing research with, and about, AMS Smart City
DOLL Copenhagen	Tech prototype testing in a suburban office park; industry membership model, and procurement program with cities	Provide testing infrastructure to members; an “open air catalogue” for buyers; networking	Smart Urban Services Lighting Metropolis	Strong outcomes; a robust financial model, high-tech projects, corporate and civic partnerships, and a growing global network; now expanding into other urban tech (integrating systems). Considering expanding to other countries with a franchise model.
i2Cat Barcelona	Non-profit “research and innovation center”; public and private sector contracts	Develop early-stage hardware and software prototypes, “from need to solution”, but does not bring them to market	Sentillo Platform Mobile Payment System	Mixed outcomes; financial instability (majority of funding from public grants) has led to prioritizing corporate contracts; public funding limits team size and compensation; now working with BCN Digital City to set up CatLab, a fab lab network of maker libraries
CPH Solutions Lab Copenhagen	PPP with city gov. and companies, to test, procure and scale; finding tech solutions to urban challenges and applying them in city departments	Managing Street Lab, a downtown tech testing site; networking; creating a new model for tender and procurement; open data platforms	Smart Parking Crowd-source Bike Lane Mapping	Mixed outcomes; disparity of the financial model and topic-definition (company-led tech testing vs. community-defined civic challenges) has caused a split into two project types (Street Lab and Solution Lab); now focusing on both tech products and a “new approach” to real-world challenges
ITK Lab Aarhus	An innovation team based in the Culture and Citizen Services Dept. that spans across city gov; a large team with diverse skills and varied projects	Citizen engagement; tech prototype testing; developing a proof-of-concept, handing it off to other departments or companies; EU-funding proposals	Dokk1 & Digital Library System Drones for City Services	Strong outcomes; an increasingly large and diverse team carries out projects in two categories: tech-first (beginning with new tech and finding civic applications) and problem-first (beginning with challenges and finding tech); now focused on internal change for city hall; starting a downtown street lab for prototype testing, inspired by CPH Solutions Lab
AMS Smart City Amsterdam	PPP with univ, city gov. and companies to issue challenges and create solutions; industry member model; organization is structured according to urban challenge topics	Program to embed in industry representatives in city gov; online repository of resources; foreign delegation visits; active networking	CityZen AMS Smart City Community & Smart City Academy	Strong outcomes; stable, lightweight model organized on urban challenge topic areas (e.g. waste, mobility, energy); now taking an increasingly global focus (Smart City Academy, online resources, delegation program & City Protocol for standards)
DULL Aarhus	Connecting regional living labs, projects and initiatives under one umbrella, to access larger funding	Regular meetings, networking, collaborative projects and EU funding proposals	Insero Living Lab Egmont Hoejskolen	Weak outcomes; DULL has ceased to exist, having served its purpose – stakeholders are now collaborating and securing funding without it; DULL has effectively transitioned into Aarhus Smart City and ITK
BCN Digital City Barcelona	Merger of the city’s tech and business dev departments; public, but works through private partnerships	Creates digital policy; applies tech inside city hall; manages a participation platform online and runs co-creation workshops	Vincles BCN Open Budget	Strong outcomes, in terms of tech policy (Barcelona Digital Plan) internal change for city hall (Open Budgeting), social innovation projects (Vincles BCN); now innovating in civic processes (tying innovation challenges, to the “urban lab” test site, to new procurement models)

2. Split: multiple sub-organizations or project tracks each specialize
Owing to the success of their initial library innovation, ITK now has a broader scope, as a design-innovation team for the municipality. "In the past two years, we have been looked to as the innovation team for any department… Part of ITK are still doing things for libraries, but a growing part of us are doing things for other departments in the municipality" (Anne Vest Hansen). One portion of ITK will stay in this role, and another will soon launch a City Lab downtown, beside Dokk1, to prototype technology, gather data, test, and demonstrate public applications. "This is going to be a place to play football, go to a concert – and we have a lot of activities planned – but beneath the pavement, and in the light posts, we are putting up sensors [and digital infrastructure]" (Bo Fristed). Companies will be invited to install new technologies – for procurement by Aarhus municipality, or for other cities to visit. The diverging focus is apparent: another interviewee in ITK stated that, "for social engagement, it doesn't make sense to have a 'lab.' Would you ask some people for feedback and not others, who are outside the lab boundary? This is against the idea of engagement" (Louise Overgaard).

Aarhus City Lab is directly inspired by Copenhagen Street Lab, where the innovation integrator is "creating a common ground for linking city problems to the marketplace – harvesting private innovation for civic projects… It's a nice way of testing, and it makes it very easy to scale up – if it works in Copenhagen, in the Street Lab, it will work anywhere… We have aimed for ultra-realism in the way we have been building the lab. That gives us very realistic conditions when we are doing innovation projects and deploying new types of equipment" (Marius Sylvestersen). Street Lab has a clear focus on high-tech systems, and has a financially stable industry membership model. And yet, it is fracturing: the program manager stated "What I've been thinking about lately, that is quite new to us, is to turn away from doing innovation, just looking into tech stuff, and actually be driven by the needs of the city. That is a very different approach… In the beginning, we were tech-focused. Now we are looking for 'wicked problems.' We are turning away from tech stuff and really looking at the needs of the city – looking at citizens. This is a big shift. It's a new approach" (Marius Sylvestersen). Moving forward, CPH Street Lab will have two distinct project categories, with two different test sites, focus areas, funding streams, and partnerships.

3. Mediate: assume a more abstract platform role
Several organizations cease to actively engage in innovation projects and transition to providing a digital repository or connecting other organizations and stakeholders. AMS Smart City began with a public–private partnership between city government, the university of applied sciences, and energy companies, with the aim to innovate in the domain of energy and sustainability. The success of this project, CityZen, led to a broader focus on urban technology, but less specificity: the organization is not directly involved with projects. "Our day-to-day business is connecting people and organizations to work on urban challenges… We don't do project management, but we keep actively in touch, facilitating innovation… partners can connect, share knowledge, share projects, ask questions" (Maaike Osieck).

The organizations that *specialize* or *split* sacrifice their role as a central hub, whereas the organizations that *mediate* sacrifice project-specific activity (i.e., ideation, prototyping, deployment). In short, both organization types have evolved significantly from their original set of goals. Yet these four cities are widely recognized as global leaders of urban technology, and – with the exception of DULL – the eight organizations continue to be important agents of that success. How has each organization evolved over time, and in its urban context? To better understand the motivations for organizational change, it is necessary to consider the city as a whole, emphasizing the relationships between the co-located organizations, and among local stakeholders.

Ecosystem-level: Four cities
Considering the development of these four cities as ecosystems, the organizations have evolved for three primary reasons: 1) to manage threats to longevity by specializing; 2) the emergence of a common language and denser networks; and 3) the diffusion of technology across the city.

1. *Longevity through specialization:* In Barcelona, i2Cat focused on contract R&D for financial reasons, but also became a key partner for BCN Digital City, both to develop urban technology infrastructure and to set up new fab labs. "Now we have a new program called CatLabs, that is still being developed, together with the municipality… We provide training, support, tools [to] support the maker community" (Josep Paradells Aspas). In Copenhagen, DOLL focuses on commercial technology and industry membership, but contracts to the city and to CPH Solutions Lab.

The latter has itself split into two project types in order to maintain conflicting outcomes of specialization: financial stability, partner relationships, and citizen engagement.

2. *A common language and denser networks:* DULL was initially a small group that pooled funding for projects in Aarhus. Several new organizations and events were soon founded, including Aarhus Smart City, Aarsome, City of Culture 2017, Media Architecture Biennale, and the annual Internet Week Denmark, which built awareness and a common language across the city. That is, the population developed a fluency with the idea of urban technology, or a "social imagination" (Archibugi, 2017). By that point, DULL had served its purpose – there was no longer a need for a translator. "I would say that the Digital Urban Living Lab, as a living lab, is dead. It's somehow finished… Cities are more mature with the smart city… [Aarhus] changed from a secretariat to calling it an ecosystem, like a network" (Jesper Algren). Most civic innovation activity now happens under the banner of Smart Aarhus, an independent entity that serves to brand projects and provide visibility. "The ecosystem works very well now, it's very well established. It's no longer 'innovation activities' with high risk – there are now a lot of business cases and use cases. It sounds more simple than it is, but it's all about networks" (Line Gerstrand Knive).

3. *Diffusion of technology:* In addition to social diffusion, urban technology is also spatially distributed throughout the city, and therefore intersects with daily life. "Copenhageners are used to being lab rats – they're used to seeing new things… This also spurs new innovations. We actually see several companies being formed. People say 'I see the city has these goals, now I can prove that,' and they develop a new solution" (Morten Kabell). A shared culture makes these demonstrations more effective, even generative of new ideas. It also and ensures longevity – ITK focuses more on building networks than on technology. "We are not selling a product, but doing projects – don't deliver a discrete thing, but create relationships. For a project to be agile and sustainably integrated, it must be based on relationships" (Louise Overgaard). In Aarhus, Barcelona, and Copenhagen, the living labs have recently partnered with the local innovation integrator on a downtown test site.

These cases show that living labs and innovation integrators are becoming increasingly interdependent with their local networks. Crucially, distributed innovation activity is happening *without* a strong-handed central broker. This clear pattern in the development of each city's ecosystem should lead us to question the hub-based model that anchors contemporary ecosystem theory: the literature assumes that a central hub is necessary to drive an open innovation process. To the contrary, I found that interaction among local businesses, citizens, organizations, and governments is happening organically (Figure 2). According to a city official in Aarhus, "We don't even think about it anymore. If we get an idea, we get in touch" (Line Gerstrand Knive). Stakeholders are connecting opportunistically project by project in response to challenges, opportunities, existing communities, technologies, etc. They are distributing their strengths and capacities, and sharing positive outcomes – constituting an "organizational field" (Storper et al., 2015) that renders the hub roles obsolete.

Discussion: From an Organization to an Organizational Field

The evolution of each organization in this study demonstrates that the hub model is obsolete. This conclusion is neither a challenge to innovation ecosystem theory nor a critique of innovation policy and its implementation. Rather, I suggest that we must extend the theoretical framework to account for two factors. First, to better account for socially-constructed institutions and how they enable a decentralized mode of innovation (Moulaert, 2001), a so-called "organizational field". Second, to better examine sociotechnical system change over time (Geels, 2004). My reading is evolutionary as well as ecosystemic.

Urban technology creates local culture, and local culture creates urban technology (Hall, 2003). The initial work of living labs and innovation integrators demonstrated the opportunity and value of civic innovation, as described by Huguenin and Jeannerat (2017). Over time, the number and scope of projects increased, creating cross-sector networks, shared culture, and mutual trust. The sociotechnical systems literature describes this activity in the context of a theory of change: "Niches are important, because they provide locations for learning processes, e.g. about technical specifications, user preferences, public policies, symbolic meanings. Niches are locations where it is possible to deviate from the rules in the existing regime. The emergence of new paths has been described as a 'process of mindful deviation'... This means that rules in technological niches are less articulated and clear-cut. There may be

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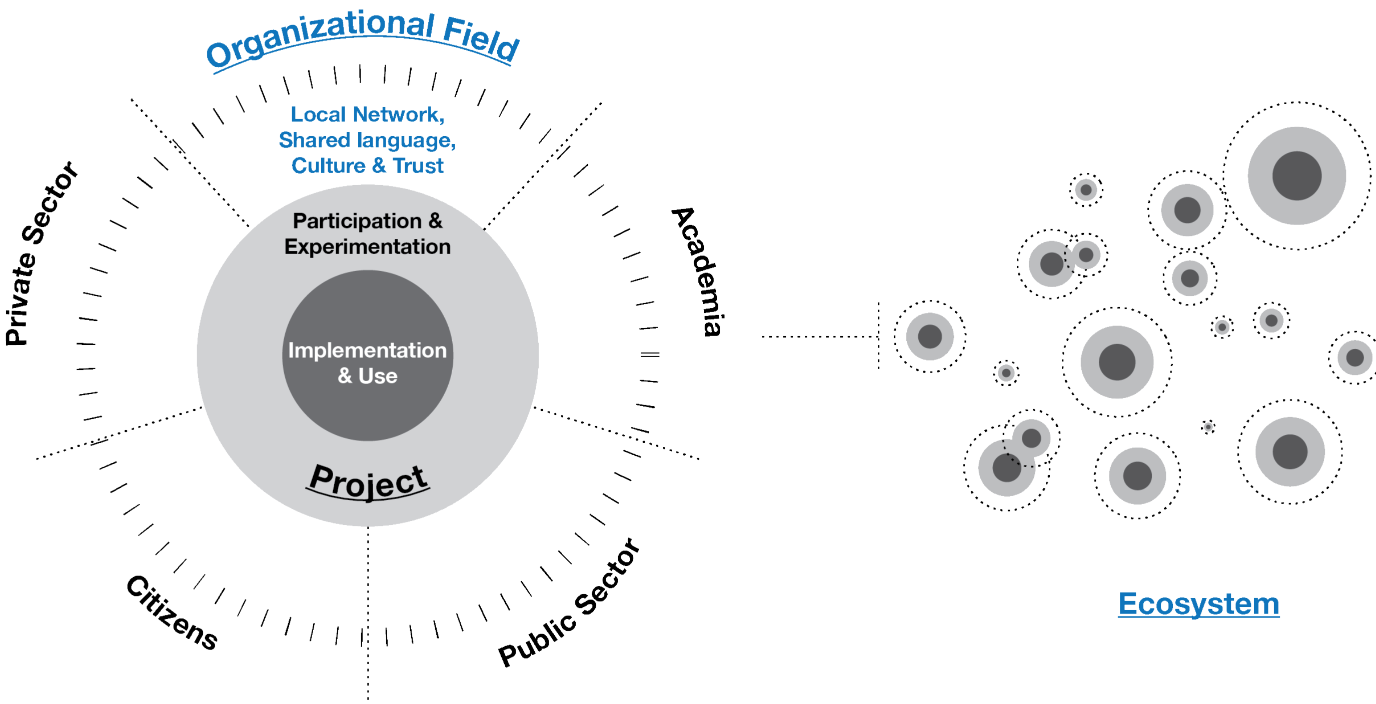

Figure 2. The Distributed Ecosystem Organization. Stakeholder groups converge around a project, through an organizational field of networks, shared language, culture, and trust. They collaborate on participation and experimentation, bringing a project to implementation and use. Many projects run simultaneously, and stakeholders cross into several different projects, share resources, or build capacities.

uncertainty about technical design rules and search heuristics, and niches provide space to learn about them" (Geels, 2004). The hubs were "niches" that allowed mindful deviation toward regime change. The organizational field then supports civic innovation by fostering participation and experimentation, as did the initial hub model.

Participation
As more and more citizens – particularly those who are not city planners, technologists, or entrepreneurs – share a vision of civic innovation, participation becomes more natural. The community was initially activated for participatory ideation, for example, by BCN Digital City's challenges and Copenhagen Solutions Lab's bike mapping. Digital maps and co-design workshop-challenges are now intuitive and broadly accessible across the population. Many and varied stakeholders are using them, effectively becoming co-creators with city government. AMS Smart City began with a corporate member program, for which companies sent an employee to be embedded in city government – ostensibly acting as a liaison between the company and the city, but more importantly, building trust and shared goals. "The [link] speeds up things. That person has embedded knowledge of both sides, and that is core to the program" (Vivienne Bolsius). Not only does this allow more effective collaboration on projects *during* the program, but it also enables agile cooperation between the city and the firms in the future, when there may be higher stakes or unexpected conditions. "To achieve a future-proof city, the network is important" (Vivienne Bolsius). Through this program, energy companies have developed smart grid applications that better account for energy policy goals while achieving efficiency, for example. They are now working on a strategy for the complete transition from gas to fully electric utilities.

Experimentation
In their original state, living labs and innovation integrators served to mitigate the risk inherent to urban experimentation by providing a controlled test site or legal fail-safes, for example. An organizational field can alleviate much of the same risk, through dense networks, mutual trust, and repeated interactions. DOLL

"ha[s] a standing relationship with the municipality. They grant us flexibility, and they are one of our consortium members… It is in an industrial area, so we can install what we like… It's ok to fail" (Kim Bostrøm). The relationship stands in place of a complex legal regime for regulatory exemptions or costly liability insurance.

A similar risk existed in De Ceuvel and the Biogas Boat. Flexibility in city zoning enabled De Ceuvel, trust among stakeholders de-risked the initial prototype, and local networks lent momentum to the collaborative project – all at the local scale. But the Biogas Boat is now impeded by national-level regulations. The project team leader states, "we currently have finished the base of the boat. We have also finished the container with digester system at a different location [in an academic lab facility]. However, we are still waiting for the permit to be issued for the project, before putting everything together. The permit process has been very complicated, and we are still not completely sure whether we will get it. The Dutch laws concerning bio-digestion are very strict, even small scale projects need an exemption." De Ceuvel and the Biogas Boat were enabled by a niche at the city level, and the hurdle of national-level regulation highlights the importance of place-based experimentation.

Godsbanen is a creative community in downtown Aarhus, home to artists and entrepreneurs, many of whom work in precariously stacked shipping containers and self-built studios. Despite its informal construction, the project is condoned by the city. Godsbanen is a story of "not having a lot of permissions, but just doing", notes Troelsen, a city official. "For me, it has always been a question of looking [the founder, Mads Peter Laursen] in the eye, and asking: 'The real necessary things, like fire risk, do you know how to manage them? And the rest, well, let's leave it for another day.' Because, otherwise, you cannot experiment, you cannot have these preliminary things. That's the reason why Godsbanen has been so great… an experimenting district. We've looked away on the rules and regulations, as long as they take care of each other" (Michael Troelsen). As a result of this experimentalist culture, Godsbanen has attracted passionate innovators who have produced a wide variety of new ideas.

The translation from urban experiments into urban systems crucially depends on the organizational field. In Aarhus, Dennis Borup Jakobsen is a drone pilot and enthusiast who was motivated to begin exploring applications of the technology for the public sector. His initial trials of drone imaging in emergency situations were allowed by police and fire departments, and they demonstrated clear gains in quality, speed, and cost efficiency. Rather than depending on ITK for technology development, however, those departments opted to start their own drone programs. ITK is assisting them with setup – securing a budget, procuring a fleet of drones, and developing operations protocol – and will then cease to be involved. The initial deployment was enabled by mutual trust, and the collaborative capacity-building ultimately allows for more effective integration, in which police and fire departments own and operate their own systems. The project will result in a city-wide emergency response system and a publication of insights and technical protocols that can be used by any city in Denmark. Furthermore, the same employee is now pursuing a drone system for infrastructure monitoring, but it conflicts with national-level regulations. The current drone experiment was allowed to operate within a fixed radius, with supervision by an operator. The new proposal is for drones to fly linearly, over long distances and outside of city limits, to evaluate power lines. This could bring efficiencies and result in significant cost reduction, but it is prohibited by current national regulations. He is working to secure exemption in order to demonstrate a proof of concept, and he ultimately hopes to change national regulatory parameters. As in the case of the Biogas Boat, the local ecosystem enabled technology beyond what is contemplated in national regulation.

In Barcelona, city government is committed to integrating the results of participatory experiments. "We use the city as a lab: to experiment, to find new solutions for common problems. The municipality gets pilots on the streets, and companies are happy to sit down with users. [At first] this was just experimentation – learning, but no buying. Now, we are going beyond… We are linking design and experimentation to procurement" (Anna Majo). Open innovation challenges and neighbourhood-level engagement are directly connected to high-level policy, procurement and regulation – a process that is traditionally fraught with cumbersome (even prohibitive) procurement hurdles. This is evidence of a broader regime shift, beyond pilot and demonstration projects.

Future Research

The observed dynamics raise three questions that merit further research. The first is developmental: Must every urban innovation ecosystem mature through a hub phase, in the process of growing an organizational field? Though the hub role ultimately became obsolete, the initial niche of living labs and innovation integrators were crucial in fostering nascent projects. Without their early activity, a common vision may never have coalesced. This should be of primary concern to policy makers contemplating the appropriate support strategy for catalyzing an urban innovation ecosystem.

The second question is scale. A common culture, participation, word-of-mouth, trust-based experiments – these are most effective as informal interactions at a small scale. A social construct of civic innovation will simply be easier in a smaller city. Tellingly, the most active city, Aarhus, is also the smallest. Problems of scale are evident in the divergence of local culture and national policies. Can trust-based, socially-constructed institutions exist robustly at a larger scale?

Finally, there is a question of formalization and the role of policy makers. The cases show evidence of the public sector building its own innovation capacity: granting area-specific regulatory exemption (Amsterdam); changing public procurement mechanisms and criteria (Barcelona); co-creating with citizens (Copenhagen); building tech-literacy across city government (Aarhus), and more. City governments appear to be acting in newly innovative ways using the tools at their disposal. Amsterdam, for example, has recently hired the original founder of AMS Smart City as the Chief Technology Officer, with a mandate of internal transformation in city government. The Deputy Mayor of Barcelona sees his role as "doing R&D in politics – no one has done this before. We are learning by doing, and really doing things" (Gerardo Pisarello Prados). But this initiative is not without conflict. How can policy makers engage and support their urban innovation ecosystems in a way that is safe, equitable, legal, and replicable? Future research will investigate the changing role of the public sector, building on theories of public entrepreneurship (Foster & Iaione, 2018; Klein et al., 2010; Ostrom, 1965, 2005).

Conclusion

A contemporary innovation ecosystem approach to urban technology leans on a hub organization: living labs and innovation integrators have been used to shepherd urban technology development. This article considered eight such organizations in cities where both models coexist. Over time, living labs and innovation integrators deviated from their original hub role, along one of three general paths: they specialized, they split into multiple entities, or they assumed a platform role (or closed entirely).

Yet, the four case cities remain at the global forefront of urban technology – each city has matured into a well-functioning innovation ecosystem. As conceptualized by Geels (2004), systems, actors, and institutions are distinct, and change occurs in their dynamic interaction. The living labs and innovation integrators provided an initial niche that fostered experimentation with a new (urban) technology category, its associated institutions, and its development pathways. Their success caused a regime shift – local stakeholders aligned around the topic and approach of civic innovation, forming an organizational field – and the ecosystem itself now serves certain core functions (enabling participation and experimentation) that were formerly filled by the hubs. This insight advances urban technology policy and scholarship: the hub model should be extended to better account for sociotechnical system development over time. It also highlights the role of the public sector, as both a supporter of the ecosystem and as an active innovator. The examined cases demonstrate that contemporary ecosystem support models have been useful niches to overcome initial hurdles, but that a sustained urban innovation ecosystem is a product of a distributed organizational field.

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Keywords: innovation systems, living lab, city, civic technology, innovation policy

How Doctoral Students and Graduates Can Facilitate Boundary Spanning between Academia and Industry

Leena Kunttu, Essi Huttu, and Yrjö Neuvo

> *"This doctoral education program is an excellent example of practical collaboration with universities. We can develop our own internal competences with the newest scientific knowledge. Moreover, we can familiarize our potential future workforce with practical industrial R&D work and with its challenges and innovation opportunities. This kind of jointly organized doctoral program is, for us, a natural channel for recruiting highly skilled experts from the academic world."*
>
> Industrial partner interviewed in this study

The mobility of scientific competences from universities to industrial firms enables firms to absorb and utilize the knowledge developed in academia. However, too few young doctors are currently employed in industry, despite the fact that they could transfer and integrate valuable academic knowledge for industrial purposes and facilitate its utilization towards commercial ends. In this article, we investigate the role of doctoral students and graduates as academic boundary spanners by presenting three joint programs between universities and industrial players that facilitate and promote the industrial involvement of doctoral students and graduates. The cases highlight the meaning of university–industry collaboration in doctoral education and present practical examples of how industrial firms may facilitate the transfer of academic knowledge to industry through jointly organized doctoral education and postdoctoral mobility programs.

Introduction

The results of academic research developed towards commercial ends provide industrial firms with a way to improve their competitiveness, and thus effective knowledge transfer between academia and industry can be a powerful source of innovation (Laursen & Salter, 2004; Perkmann et al., 2013; Siegel et al., 2004). The ability of an industry sector to utilize the knowledge of a highly educated workforce is an important factor in improving its innovative capacity and the economy overall (Weckowska, 2015). However, maintaining competitiveness and further strengthening it requires constant monitoring and analysis of new technological and operational trends. Intensifying international competition and accelerating speed of change require that industrial firms not only have the ability to implement the latest innovations, but also actively create new innovations (Gassmann et al., 2010).

One of the most essential ways of transferring knowledge is to facilitate the mobility of academics to industry and vice versa. Recruiting newly graduated doctors has been found to be an effective method of transferring and integrating the latest academic knowledge for industrial purposes (Kunttu, 2017). Doctors have the most up-to-date scholarly knowledge in their field, and they are capable of attacking demanding problems with scientific rigour. However, relatively few doctors are actually employed in industrial firms in Western Europe (Auriol et al., 2013), despite the fact that the countries in this region have graduated a rapidly increasing number of doctors in recent decades. For instance, in high-technology countries such as Finland and Sweden, only about 25–30% graduated doctors are employed in private sector.

When people move between academia and industry, they have to cross different organizational boundaries

(Rajalo & Vadi, 2017), because the institutions operate under different environments and cultures caused by their own norms, motives, and values (Bruneel et al., 2010). For this reason, university–industry boundaries often represent obstacles to establishing close interactions between actors on either side. Reflecting this challenge, doctoral students working in universities often focus on relatively narrow topics defined by academic priorities, but without a clear connection to real-world industrial work (Kunttu, 2017). Therefore, facilitating practices for boundary spanning and relevant social processes are necessary to open new avenues for interaction and integration of doctoral students with an industrial environment.

Thus, boundary spanning is an important skill or behaviour for actors who actively aim at transferring academic knowledge between academia and industry (Ankrah & Al-Tabbaa, 2015). These boundary actors may serve as a bridge between industrial firms ("customers") and academic institutions ("suppliers"), who operate in different environments with different motives, cultures, and actions (Siegel et al., 2004). The doctoral candidates and young doctors who engage in industrial domains represent boundary actors who may operate across the boundary between university and industry and thus help to transfer knowledge in both directions.

Previous research has highlighted the importance of the academic engagement and knowledge transfer in university–industry collaboration (Ankrah & Al-Tabbaa, 2015; Ankrah et al., 2013; Perkmann et al., 2013), but this research falls short in its analysis of educational collaboration and in the role of students and graduates as boundary spanners. As indicated by Ankrah and Al-Tabbaa (2015) in their recent systematic literature review on university–industry collaboration: "...the impact of academic engagement in the process of UIC [university–industry collaboration] is almost overlooked. For example, none of the reviewed studies have addressed the consequences of this engagement on, for example, teaching and learning experience of students affiliated with universities that engaged with the industry. This line of research can provide supporting evidence to the intangible potential value of the UIC (Perkmann et al., 2013)."

To address this gap, this study intends to answer the following research questions:

- *How can jointly organized doctoral education programs facilitate the mobility of doctoral students and graduates from academia to industry?*
- *What kinds of boundary spanning practices are related to these programs?*

To address these questions, we present a case study investigating three doctoral education programs that focus on the mobility of doctoral graduates from academia to industry. All these programs aim at familiarizing the students with an industrial way of working and by providing them with real industrial problems to which they can apply their academic knowledge and problem-solving skills. By using these kinds of educational programs, the universities and industry are able together lowering the boundaries between these two types of institutions and facilitate effective knowledge transfer between them.

The remainder of the article is organized as follows. The following section describes three cases of doctoral education programs designed to facilitate boundary spanning between academia and industry. After that, we present and discuss our findings. Next, we highlight the practical implications of the findings. Finally, we offer conclusions.

Three Cases of Boundary Spanning

This study presents three cases of boundary spanning in the context of university–industry collaboration, as summarized in Table 1. The authors of this article are the main organizers of the courses described in the three cases (Case 1: Neuvo; Case 2: Kunttu; Case 3: Huttu) and are the main source of information about these cases. Additional data used in the case descriptions included interviews and feedback from the course participants as well as materials produced during the courses.

Case 1: Bit Bang

The first case presents the Bit Bang doctoral training course, which has been run annually throughout the full academic year at Aalto University, Finland, since 2008. This postgraduate course is built around a general theme specified every year. The course relies on multidisciplinary and multinational teamwork assignments in the area of the course theme, and top-class guest lectures from industry leaders. The course adapts Nokia's top management training program to the academic environment. The course aims at facilitating collaboration across disciplines and, what is even more important, provides a bridge between academic post-graduate studies and industrial real-world challenges. The students work on specific assignments in student teams under the supervision of experienced tutors, and they

Table 1. A summary of three cases of boundary spanning in university–industry collaboration

	Case 1	Case 2	Case 3
Activity name	Bit Bang	Nokia Mobile Imaging	PoDoCo Program
University partners	Aalto University	Tampere University of Technology, Aalto University	Several universities in Finland
Industrial partners	Nokia and other Finnish technology companies	Nokia	An industrial consortium
Target group	Doctoral students	Doctoral students	Doctoral graduates
Activities	Teamwork on course topics; guest lectures from industry; a week-long study tour	Teamwork on course topics; guest lectures from academia and industry	Research grant for a broad research phase followed by a targeted research phase funded by the industrial partner
Deliverables	An academic report authored by each student team	Presentations and reports	Company-specific research results
Impact on students	The majority of student participants were hired by industrial firms after doctoral graduation.		
Impact on companies	The companies benefitted from new scientific knowledge and relationship building with potential new employees.		

jointly author a report on their team-specific topic. The highlight of the course is a week-long intensive study tour to a globally recognized region of research, innovation, and business. Past locations for the study tour have included Shangai, Tokyo, Bangalore, New York, and California, and each tour includes both company and academic site visits. The course has been organized nine times, and the total number of participants has been about 200. The majority of the students have been hired by industrial firms after following their graduation, and many also still participate in the program as tutors or guest lecturers or are still actively involved by attending Bit Bang events. Papers produced by students during their Bit Bang collaboration have produced interesting results: many participants have gone on to write conference papers and journal articles based on the joint reports written in class.

Case 2: Nokia Mobile Imaging

The second case presents a series of company-specific university collaboration courses organized between Nokia and Finnish universities during 2008–2010. The purpose of the courses was to deepen understanding of topics related to image analysis and processing in mobile devices. The courses were built on the existing and quite intensive research collaboration between Nokia imaging software development and a consortium of Finnish university research groups. The main idea in organizing the courses was to facilitate effective knowledge transfer between Nokia's imaging R&D team and the university research groups on selected topics in mobile imaging. In this manner, the academics were encouraged to present the most recent research-based knowledge in this area, whereas the company R&D staff brought their experience-based knowledge in the courses. The teaching was based on weekly meetings in which either a university professor or an R&D specialist from Nokia gave a lecture on a selected topic in their area of specialty. After the lecture, they all discussed the topic together. The team work was related to the course content and was based on a selected practical industrial problem, to which the teams were searching for a solution with the guidance of academic and industrial supervisors. The target audience for the courses was Nokia R&D staff and university doctoral students. There also were doctoral students who already worked in Nokia R&D, but who undertook doctoral studies after being encouraged by this kind of learning opportunity.

The doctoral students participating in the courses were given credits on the passed courses. The courses were organized in two consequent academic years around different themes. The theme for the first course was *Mobile Imaging* and for the second course theme was *Image Quality*. The total number of participants for both courses was about 60 people who were about equally divided between industrial R&D staff and academics.

Case 3: The PoDoCo program

The third case, the PoDoCo (PostDocs in Companies) program, is a joint initiative of Finnish universities, industry, and foundations. The aim of the program is to support the transition of doctoral graduates into private sector careers and, at the same time, enhance the strategic renewal of companies. PoDoCo facilitates novel meetings and matches newly graduated doctors with companies, and it financially supports the collaboration projects between doctors and companies. Annually, the PoDoCo program receives almost one million Euros annually in funding from its nine participating foundations and from companies participating in the program.

PoDoCo projects consist of two phases: broad research and targeted research. The aim of the first phase is to create far-reaching knowledge on a research topic of interest to both the doctor and the company. The PoDoCo foundation pool offers research grants of 6–12 months for this first phase. After the broad research phase has been completed, the company hires the doctor to deepen the research results and to create company-specific insights during the targeted research phase, which also lasts 6–12 months and is funded by the industrial partner.

The PoDoCo program has been running since 2015 and, so far, the program has received extremely positive responses from both companies and doctors. For companies, the PoDoCo program offers an opportunity to investigate new strategic openings with the help of talented doctors who are familiar with scientific analysis and synthesis methods and who possess the latest scientific knowledge. For doctors, the PoDoCo program offers an opportunity to work in the private sector, gain industrial experience, and establish important networks with companies. The result is a win-win situation where academic research is supporting the strategic renewal of companies and where doctors gain industrial experience. So far, 64 PoDoCo grants have been awarded, with the first PoDoCo collaboration projects starting in the spring of 2016 and ending during 2017. In the majority of these cases, following the completion of the research, the participating doctors have been hired by the companies they collaborated with, meaning that the PoDoCo program has successfully enabled a smooth transition from academia to the private sector. The PoDoCo program has also benefitted participating companies, many of whom have reported that the research conducted during the PoDoCo program has opened new avenues for growth.

Results and Discussion

The three doctoral education programs presented in this article show that collaborative programs in doctoral education train both industrial actors and academics through boundary-spanning activities.

A key finding of this study was that collaborative doctoral education programs jointly organized by academia and industry clearly facilitate and motivate the doctoral students and graduates to cross the border between academia and industry. A clear majority of the students participating in the programs continued their careers in industry after doctoral graduation.

We also found that the industrial players involved in the collaboration found it particularly beneficial that doctoral students were able to bring new and fresh ideas, innovative mindsets, and new scientific knowledge into the industrial domain. They also appreciated the opportunity to employ the newly graduated doctors into their internal R&D tasks, which facilitates the commercialization process of the university innovations developed in the doctoral projects. In this manner, the programs help the industrial firms to open doors for potential new employees with high scientific knowledge and skills, whose recruitment increases the firms' internal knowledge resources and capabilities.

The doctoral students underlined the importance of industrial experience and understanding of the industrial way of working that is possible to achieve by participating in the collaboration programs. Thus, such programs lower the threshold for doctoral graduates to transfer to an industrial career.

On the industry side, a related finding was that industrial R&D staff involving the collaboration were able to familiarize themselves with academic research and education. This, in turn, helps bring industry and academia closer to each other by establishing personal-level contacts and networks and by increasing mutual trust and relational capital, which are key factors to overcome organizational and cultural barriers between academia and industry (Bruneel et al., 2010). In this way, the programs facilitate boundary spanning between these two types of institutions (Siegel et al., 2004).

Also, the Nokia Mobile Imaging case showed that jointly organized doctoral education programs may encourage technical staff working in industrial firms to start or continue doctoral studies. In addition to this, getting as many industrial employees as possible to participate the programs as students, mentors, supervisors, lecturers, or audience members can increase positive attitudes and mindsets towards university collaboration, which in turn makes them potential boundary actors (Siegel et al., 2004), and also promotes the research collaboration between universities and industry, as suggested by Kunttu (2017).

Practical Implications

In this article, we have presented three cases of doctoral education programs aiming at facilitating boundary spanning and mobility between industry and academia. However, these kinds of jointly organized educational programs represent rare examples in doctoral education in Finland and appear to be even rarer within an international context. For this reason, the collaborative practices for facilitating mobility presented in the cases can also be widely utilized in almost all kinds of doctoral education programs, and also in companies that do not have opportunities to participate in doctoral education programs. The key practices identified in this article include:

1. Involving industrial experts in the doctoral education program as guest lecturers, mentors, or supervisors.

2. Providing the doctoral student groups with project work topics that are directly connected to real-world industrial challenges.

3. Providing the doctoral students with opportunities for training or working on the relevant industrial topics during the doctoral studies.

4. Providing the doctoral students with research grants on a topic that is of industrial partner's interest.

5. Providing the doctoral students with the opportunity to continue the research work after graduation as company-internal employees.

Conclusion

This study sought to better understand how to address the problem that too few young doctors select industrial career after their graduation, despite the fact that these newly graduated doctors possess the latest scientific knowledge that could be applied towards commercial ends in the industrial domain. In this article, we showed that collaborative doctoral education jointly organized by academia and industry is not only able to encourage doctoral students to undertake industrial careers, but also to facilitate wider boundary-spanning activities between these institutions and, in this manner, lower organizational and cultural barriers between them.

All three doctoral education cases presented in this article reveal that industrial R&D may greatly benefit from participation in collaborative doctoral education by means of new scientific competences, fresh insights, and innovation mindsets provided by doctoral students and newly graduated doctors engaging in the industrial R&D. As boundary spanners, doctoral students and graduates can form a bridge between academia and industry. By engaging in the doctoral education and postdoctoral transfer programs, industrial firms are able to obtain valuable competences by engaging with doctoral students and graduates who not only transfer scientific knowledge to the firm but also take an active role in integrating and utilizing the knowledge towards commercial ends. In addition to ensuring an effective transfer channel for academic knowledge to industrial purposes, collaboration in these programs involves people from both sides of university–industry boundary in the collaboration and thus facilitates new forms of collaboration and trust building.

How Doctoral Students and Graduates Can Facilitate Boundary Spanning between Academia and Industry *Leena Kunttu, Essi Huttu, and Yrjö Neuvo*

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Leena Kunttu received her PhD degree in Information Technology (Signal Processing) from the Tampere University of Technology, Finland, in 2006. Between 2007 and 2012, she served as Senior Manager in an area of innovation at the Nokia Corporation. During her career at Nokia, she led a number of collaborative projects between the company and external research institutes, such as universities. She also led and participated in joint educational activities between Nokia and universities. Since 2015, Dr. Kunttu has served as a researcher in an area of innovation at the University of Vaasa, while also carrying out PhD studies in industrial innovation. Her current research interests include university–industry collaboration, educational involvement, and the commercialization of university technologies.

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