



# Identifying potentially disruptive trends by means of keyword network analysis



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## ABSTRACT

Identifying potentially disruptive technologies is crucial to safeguarding competitive advantage by enabling stakeholders to assign resources in a manner that increases the chances of exploiting the disruption and/or mitigating the ensuing risks. However, disruptive technologies and emergent trends within known disruptive domains are mostly identified ex-post. This paper contributes to the ex-ante prediction of emergent technologies within disruptive domains by proposing a literature-driven method for the forecasting of potentially disruptive technological trends. It adopts a keyword network analysis and visualisation approach for uncovering emergent thematic, structural and temporal developments within publications and applies it as a forecasting tool to an empirical study of seven disruptive domains: 3D Printing, Big Data, Bitcoin, Cloud Technologies, Internet of Things, MOOCs and Social Media. Maturing trends were found to share influential common topics identified by high degree, betweenness and closeness centrality scores. Niche and potentially emerging trends within groups were detected by means of eccentricity and farness metrics. Visualisation techniques were found effective for further clarification and trend identification. Finally, potentially disruptive trends within domains were found to be associated with high closeness paired with low degree centrality. The findings were distilled into a framework for assisting the forecasting of potentially disruptive trends.

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## 1. Introduction

In an ever-changing technological landscape where innovation is a crucial driver for economic growth and survival, it is desirable to be able to predict which technologies, when established, have the potential to revolutionise an industry, create new markets, and increase accessibility and affordability. Studies describing innovation trends, trajectories and future patterns identify drivers such as geographical factors, firm clusters, knowledge flows and spill-over effects (Doloreux and Shearmur, 2012; Gertler and Levitte, 2005; Hausman and Johnston, 2014; Huber, 2012; Tappeiner et al., 2008). With information technology an integral part of all aspects of organisational life, research on IT innovation constitutes an important driver of organisational competitiveness (Fichman, 2004; Hamel, 1998) promoting scalability, sustainability and affordability (Helal, 2015).

Unlike sustaining innovation which supports established improvements to existing products and services, disruptive innovation is defined as the process of transforming a product or service that historically has been accessible at the top of a market access (i.e. for a high price or

specialised skill-set) to become accessible to a new and larger population of consumers at the bottom of that market (Christensen, 1997). Disruptive innovation creates a new market and value network which eventually disrupt and displace their predecessors (Christensen and Raynor, 2003; Christensen et al., 2004). Depending on the application aspect, disruptive innovations can be categorised as product, business-model or technological innovations (Markides, 2006). A disruptive technology can be thought of as a technology that changes the essence of competition among firms by transforming the performance metrics (Danneels, 2004).

There is evidence suggesting that smaller firms have a potential advantage over larger organisations in that they can leverage their capabilities for innovative solutions and are more agile in dealing with organisational change and with managing disruptive innovation (Hyvonen and Touminen, 2006; Moore and Manning, 2009). In contrast, organisational barriers in large corporations may hinder innovation. These barriers include the existence of a successful dominant design or profitable business concept, possible inability to learn and adopt change, a risk-averse management, the mishandling of the innovation process and an absent or underdeveloped infrastructure (Assink, 2006). Learning competencies in smaller but established companies have been found to have high impact on the degree of novelty of innovation (Amara et al., 2008), which influences marketing positioning and boosts growth (Dotsika and Patrick, 2013). European funding, such as

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the Open and Disruptive Innovation (ODI, 2014) scheme, aims to promote ideas of high disruptive potential through business innovation grants and the facilitation of consequent commercial exploitation.

Despite these initiatives disruptive innovation trajectory and forecasting are inadequately covered and poorly understood. Disruptive technologies are difficult to predict and are mostly identified ex post (Christensen and Raynor, 2003). Studies on disruptive innovation forecasting recognise the potential of literature based methods (Kostoff et al., 2004). However, no actual method has been proposed. Can the existing literature on current disruptive technologies provide clues on determining future potential trends? What can we learn from the bibliographic differences between business and academic publications on disruptive technologies? And, can keyword network analysis help identify disruptive trends and influencing themes by interpreting the thematic relationships within subject groups? These are the questions addressed in this paper. In it we present a literature-founded approach to uncovering emergent, potentially disruptive trends by analysing the sub-theme associations and timeline of disruptive technologies identified through their presence in business and scholarly articles. In order to do this, we first:

- Identify the major current trends in the field of disruptive technologies.
- Determine and compare the distribution of each of these trends from onset to present in leading business reports and academic publications.

Then, adopting a network approach, we perform a statistical and visual analysis of the data concentrating on its thematic, structural and temporal characteristics with the intention to:

- Investigate and demonstrate the thematic and temporal relationships of relevant academic publications in terms of domain, influence and popularity
- Propose a literature-based framework for assisting the forecasting of emergent trends within disruptive domains.

The rest of the paper is organised as follows: Section 2 reviews disruptive technologies' forecasting. Section 3 presents the research design and data collection and Section 4 follows the data analysis and interpretation. We discuss our findings in Section 5 and identify the implications for research and practice. In the last section, we draw our conclusions and outline future work.

## 2. Forecasting the trajectory of disruptive technologies

Identifying new potentially disruptive technologies and/or new disruptive trends and applications is a challenge that may be met by anticipating change and preparing for it by way of understanding the dynamics of innovation, identifying the drivers of the future and collecting intelligence (Paap and Katz, 2004). Dissatisfied with plain empirical evidence and ex-post success verification, researchers in the field have debated the predictive use of the theory of technological disruption (Christensen, 2006; Danneels, 2004). Models and methods proposed include diffusion forecasting which takes into account the servicing of multiple markets (Linton, 2002), measures of disruptiveness for predicting the disruptive innovation potential of incumbent firms (Govindarajan and Kopalle, 2005, 2006) and research on R&D strategies for the purposeful creation of technologies with high disruptive potential (Yu and Hang, 2011).

Disruptive innovations are mostly identified ex post (Christensen and Raynor, 2003). Ex ante prediction frameworks are not well established. Adapting existing technology forecasting methods can help with forecasting potentially disruptive technologies (Danneels, 2004) while ex ante predictions about companies with potential to develop disruptive innovations can be made through the disruptive innovation framework (Govindarajan and Kopalle, 2006). Technology roadmapping is often used for the forecasting of disruptive technologies (Phaal et al., 2004; Vojak and Chambers, 2004). Use of scenarios can be

successfully applied to aid analysis that particularly suits disruptive innovation (Drew, 2006). Approaches to identifying disruptive technologies are discussed in existing roadmaps. Literature-based discovery is recognised as a starting point which leads to better results when combined with a roadmap development process (Kostoff et al., 2004) but not as a method in its own right. Obstacles include the frequent lack of standards, dominant designs and the potential presence of competing and/or complementary manufacturing technologies (Walsh, 2004) as well as a variety of uncertainty factors including technological, market, regulatory/institutional and social/political uncertainty (Jalonen, 2011).

Perspective is critical in understanding and untangling competing terminology issues. For identification and classification purposes it is important to consider marketing, technological, and macro- and micro-level perspectives (Garcia and Calantone, 2002). Within a business setting, innovation is managed differently within large companies than it is in small firms (Dotsika and Patrick, 2013).

Existing approaches of ex ante identification of disruptive innovation can be grouped into three categories depending on the focus and analysis position (Keller and Husig, 2009). Scoring models analyse the disruptive potential of new innovations (Rafii and Kampa, 2002; Christensen et al., 2004; Hüsigg et al., 2005; Govindarajan and Kopalle, 2006; Sainio and Puumalainen, 2007; Ganguly et al., 2008; Keller and Husig, 2009; Hang et al., 2011). The other two groups use scenario analysis, simulating a potential entry and distribution. Economic models focus on an economic perspective (Adner, 2002; Adner and Zemsky, 2001; Schmidt, 2008) and situational models focus on other aspects (Kostoff, 2004; Paap and Katz, 2004; Vojak and Chambers, 2004).

Continuous monitoring of the technology landscape in one's own industry to identify technologies that are better performance drivers is a necessity (Paap and Katz, 2004). Integrating the literature in technology forecasting is one way to deal with this and help to reveal trends, identify technology or product candidates for potential disruptive innovation (Young et al., 2008; Yu and Hang, 2010).

Literature-based detection of disruptive technologies and, in particular, disruptive trends within existing disruptive domains, is recognised among the studies on disruptive innovation forecasting (Fagerberg, 2004; Kostoff et al., 2004; Young et al., 2008). Keyword co-occurrence and network analysis methods have been used for bibliometric analysis in the area to identify technological trends (Choi et al., 2011a; Li et al., 2016; Wu, 2016), analyse research topics (Wang et al., 2016), follow their evolution (Ye et al., 2015) and track the development of innovation system research (Liu et al., 2015). Similar methods have been implemented on patent analysis for the identification of appropriate technology opportunities (Kim et al., 2014; Lee et al., 2014), the detection of technology trends, significant patents and novel technologies that enable strategic technology planning (Park et al., 2013) and the improvement of technology development efficiency (Choi and Hwang, 2014). Social network analysis methods focusing on centrality measures have been successfully employed to identify dominant areas of operations management research (Behara et al., 2014) while visualisation methods have been found effective in creating knowledge maps exploring research themes, monitor research trends and discover interdependencies between research areas (Lee and Su, 2010; Yang et al., 2016; Yoon et al., 2010). Forecasting research has employed keyword network analysis focusing on clustering and distribution to identify and predict research trends (Choi et al., 2011b) and visualisation to understand advances of emerging technologies (Kim et al., 2008).

The research presented in this paper extends the use of network analysis in forecasting by employing positional influence metrics and visualisation to complement distribution and clustering and by applying it in the domain of disruptive technologies. Our contribution is a literature-based method and resulting framework for the identification and forecasting of emergent technologies within disruptive domains. We assume known disruptive domains and existing publications on these domains.

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