THE DYNAMICS OF DISTRIBUTED DIGITAL INNOVATION

AN ANALYSIS OF THE RADICAL TRANSFORMATION OF FRONTLINE CUSTOMER SERVICE IN A UK RETAIL BANK

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Illustrations and Tables

Declaration

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. It has been composed by myself and has not been submitted in any previous application for any degree. The named author carried out the work presented, including data collection and analysis. The author has in reworked versions submitted parts of this thesis to the following journals and conferences (see appendix 2 for abstracts):

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Abstract

This thesis shows how small-scale actions can accumulate into radical organisational transformations catalysed and enhanced through digital technology. Current literature on digital innovation and path creation offer powerful views on such transformations emphasising the vistas of opportunity opened by generative and flexible digital technology, and how new technology can be leveraged for organisational transformation.

Digital transformations have predominantly been portrayed from the centralised perspective of a manager, entrepreneur or group of designers. However, emerging research on distributed digital innovation increasingly emphasises how radical transformations emerge from widely distributed networks as a result of contributions from multiple heterogeneous actors. The aim of this thesis is to inform emerging theory on distributed digital innovation by explaining the ways in which multiple digitally distributed actions can combine into radical organisational transformations.

To this end, a two-year, multi-method case study of the distributed and radical digital transformation of frontline customer service at Barclays' retail bank was conducted. The research design combines traditional qualitative research techniques with new computational methods in a 'grounded computational analysis' framework. This allows for a new empirical and conceptual perspective on the agency dynamics of distributed digital innovation.

The findings suggest that organisational transformations can occur as a consequence of accumulation of multiple small-scale actions, contingent upon at least the following four factors: a) the sequence of previous transformations; b) the composition and structure of the innovation network; c) the co-occurrence of proposition, opposition and synthesis as micro-level interactions; d) the specific configurations of enacted agency dynamics.

These findings are used to build a grounded process theory of 'double-cumulative synthesis' explaining the transformational power of specific configurations of digital agency dynamics. This contributes to the literature on distributed digital innovation by conceptualising the dynamics and structure of distributed agency dynamics that accumulate into radical organisational transformations.

Preface

This thesis explores how the emergence of a new breed of digital technology requires radical rethinking of how we conceptualise and study the significant organisational transformations related to digitalisation. Through almost a decade in the IT and communication technology industry previous to pursuing and academic career, I witnessed radical transformations of the design, characteristics and impact of digital technology and experienced first-hand how the concepts and methods of the past proved inadequate for even simple business tasks in a digitalised world.

My journey into academia, and initial motivation for pursuing a PhD, started with a simple question: Why do our users upgrade? At the time, I was working for a cloud collaboration start-up that had recently been acquired by a large multinational IT company for what seemed like a vast sum of money. As a part of scaling and expanding the newly acquired business, our new employers were naturally interested in knowing the reasons why our freemium business model was successful in converting free users to paying customers. We had extensive data about user behaviours from the moment they logged onto the website and into the nitty-gritty details of their everyday collaboration patterns and we felt well equipped to provide a plausible answer. However, after running extensive regression analyses controlling for a myriad of factors, we came up with no significantly strong explanation. Discouraged by our failure we made the journey from our newly established San Francisco office to engage with an expert group of MBA students to give it a try. Surely their far more advanced regression analyses would yield answers that were superior to what we had come up with. They did, but only by a small margin. Essentially we were left with the same simple, and given the context quite reasonable, question and no good answer to give. After some reflection, I concluded that what we were experiencing was something fundamentally new and that trying to understand it using the established concepts and methods was therefore a moot undertaking. We had made two fundamental mistakes.

First, our assumption of technology as a static object that can be used interchangeably as an independent variable was far off from the reality we were building. Our collaboration platform was fluid and evolving, continuously adapting to the specific and localised needs of particular groups of users in highly specific situations ranging from financial consulting to pool maintenance at various points in the histories of heterogeneous businesses at cultural and geographical locations distributed across the globe.

Secondly, the methods we applied were ill suited for an emergent, connected world where normally distributed data sets of autonomous samples are rare and far between. Our users were connected and collaborating across organisational and geographical boundaries by design. The very fundamental point of building a social collaboration tool is to connect users and engage them in shared activities where the actions of one user were meant, intentionally and by design, to affect the behaviour of other users. This meant there was little help to be found in traditional business statistics books for answering the most fundamental questions about our business. A new range of methods and indeed a new way of thinking about digital technology and digital innovation was needed to understand the connected and collaborative digital reality in which we found ourselves.

Indeed, research published by UK telecoms regulator Ofcom shows that social networking is driving the UK’s international lead for mobile device adoption and usage with 58% owning a smart phone and 19% tablet ownership in December 2012 (Ofcom 2012). This suggests that distributed collaboration and innovation practices in the UK are changing with severe implications for the interaction between employee groups within the company as well as for customer relations.

One particular industry, the financial services industry has recently seen an increase in new digital innovations with the purpose of enabling customers to self-service but though much previous research has focused on customer adoption of new banking technologies, especially internet banking (Akinci et al. 2004; Al-Ashban and Burney 2001; Chang 2003; Joseph et al. 2005), the nature and effects of digital innovation on frontline customer service remain under-researched.

While the digital transition of personal banking seemingly changes the entire industry, the importance of retail banking is not diminishing for the individual bank. Rather banks find themselves in a phase of transition that will determine the future of retail banking. Statistics suggest that the importance of branches is not diminishing as a result of self-service technologies. A recent for a 62% increase has been recorded in the number of branches per financial institution within the UK between 2001 and 2011 due to consolidation in the retail banking market despite wide spread proliferation of self-service technologies (Radhakrishnan et al. 2011). This illustrates that a transformation of retail banking has been underway for some time and raises the question of what is the nature of this transformation.

The research presented in this thesis addresses this question by studying the radical transformation of customer service and retail banking at in a major retail bank in the UK, Barclays bank. In doing so it also attempts a first step towards answering the question of how to study the novel innovation processes associated with radical digital transformation. My hope is that this study will contribute to an understanding of the distributed processes of digitalisation and the ways in which we study and manage them.

1. INTRODUCTION

The proliferation of digital technology combining internet connectivity and mobile computing with enterprise systems has fostered a new breed of disruptive digital innovation resulting in radical organisational transformations in a range of different firms as it shifts entire industries from their plotted course (Lyytinen and Rose 2003). Empirical research in as diverse contexts as payment infrastructures (Scott and Zachariadis 2012), healthcare commissioning groups (Miani and Zachariadis 2011), and car manufacturing companies (Lee and Berente 2012; Svahn et al. 2009) has established that digital innovation affects radical organisational transformations. This thesis aims to provide insights that might lead to answering *how* such radical digital transformations happen by investigating the distributed micro-dynamics that lead to radical organisational transformations catalysed by emerging digital technology.

This chapter first establishes the motivation and scope of the research presented in this thesis before formulating a problem statement and research questions. Next, it introduces the research objectives and approach taken to answer the research questions before defining specific contribution targets.

1.1 Motivation and Scope of Research

The capability for managers to anticipate, plan and implement changes to technological trajectories has always been pivotal to the success and performance of a wide variety of companies (Abernathy and Clark 1993; Garud et al. 2010; Tushman and Anderson 1986). Digital technology forces researchers and practitioners alike to rethink innovation processes not only in terms of the values we embed in technological artefacts (Nandhakumar et al. 2013), but also in terms of the agentic dynamics that shape how new technologies, ideas and services are generated (Yoo et al. 2010).

Making decisions about radical changes to the organisation of core business processes is traditionally seen as the privilege of a select group of board members or top executives. However, recently emerging digital technologies have increasingly distributed coordination and control of innovation processes (Yoo et al. 2008) enabling small-scale innovations to combine into radical transformations of technological, cognitive and organisational structures (Garud and Karnøe 2003; Garud and Rappa 1994). This distribution of decision-making pertaining to distributed digital innovation represents a significant challenge for managers as the drivers of ever increasing change move from existing organisational structures to emerging innovation networks. This challenge of managing distributed digital innovation is manifested in two ways.

First, a lack of knowledge about the nature and characteristics of dynamics of distributed digital innovation renders it difficult to make informed strategic decisions about the direction and outcomes of digital transformation. Following from this, the effects of management decisions on the direction of organisational trajectories become uncertain. These uncertainties stem from a lack of knowledge about the dynamics by which radical transformations emerge through distributed innovation networks.

Digital innovation has been defined as the new waves of related innovation practices that follow the digitisation of physical artefacts (Andersson et al. 2008; Boland et al. 2007; Henfridsson, Mathiassen, et al. 2009; Svahn et al. 2009; Zammuto et al. 2007). As technological infrastructures evolve to facilitate distributed social interaction, innovation practices are increasingly taking place in the context of distributed innovation networks (Yoo et al. 2008; Yoo et al. 2010). Existing streams of research on technological trajectories based on evolutionary economics (Arthur 1989; Nelson and Winter 1977), sociomateriality (Leonardi 2013a; Pickering 1993) and actor network theory (ANT) (Garud and Karnøe 2001, 2003) in various ways conceptualise trajectory shaping activities as distributed processes. While all three streams of research present powerful views on agency in distributed innovation, actor network theory is based on a fundamental conceptualisation of sociotechnical networks as the arena in which distributed technological change is enacted (Callon 1981; Latour 1991a, 1992a).

Recent developments in ANT leverage the increasing availability of digital trace data and computational tools to analyse them. This has inspired an emerging stream of empirical research tracing distributed innovation activities (Madsen 2012; Meyer 2009; Ricci 2010; Venturini 2009, 2012; Whatmore 2009). While this research points to an important and relevant problem, and goes a long way in unravelling the complex webs of distributed innovation, deeper understanding of the agency dynamics by which localised and distributed actions combine to form radical organisational transformations in still needed (Venturini and Latour 2010).

An increasing volume of information systems (IS) research focuses on the distributed agency of such digital transformations (Eaton et al. 2015; Hanseth and Lyytinen 2010; Yoo et al. 2010). Despite this emerging research, new methods and theoretical frameworks of distributed agency are yet to be adopted in the IS field (Hedman et al. 2013). The reasons for this gap in the body of IS research can largely be found in the ways in which digital artefacts have mainly remained exogenous to IS theorising (Grover and Lyytinen 2015). So far, agency dynamics involving digital artefacts have been conceptualised in at least three distinct ways, that each in its own way perpetuates the conceptualisation of digital artefacts in existing IS literature as extant and secondary to human agency. The three highly general yet distinctive conceptualisations include: 1) technology as a static and inanimate object of human agency; 2) technology as context for human interactions; and 3) technology as enacted through practice.

The first category includes research that conceptualises digital technology as an inanimate object of human agency that functions in one of two ways; as the static product of a design process or as an independent variable predicting IT adoption or use. One example of the former can be found in research on IT design that views technology as a raw material that can be moulded, forged and combined to 'fit' or enhance a specific set of human activities (Ba et al. 2001; Baldwin and Clark 2000; Lucas Jr 1991). In much the same way, IS adoption research applying variations of the technology acceptance model (TAM) excludes IT from the model to focus research attention exclusively on human intentions and user behaviours. As a general observation, IS adoption research sees technology as an object of human agency by, for example, constructing 'intention to use' as an independent variable. By treating digital artefacts as an object of either design or use activities, this stream of research denies technology any claim to agency (Davis 1989; Szajna 1996). Consequently, it adopts the perspective of specific human actors while ignoring the agency of the information system in part or as a whole.

The second conceptualisation of agency in distributed digital innovation broadly revolves around topics such as virtual teams (Kanawattanachai and Yoo

2007; Robert et al. 2008; Sarker et al. 2011), affordances (Gibson 1977; Leonardi 2011, 2013b; Majchrzak and Markus 2012), and connectivity (Kolb 2008; Kolb et al. 2009). This strand of research views technology as a context for human agency, which enables certain kinds of human action and inhibits others. That is, technology is considered as a milieu within which human agency can unfold under the influence of certain affordances and constraints provided by digital technology.

Recently, a new perspective on technological agency has emerged in IT innovation research, building on theoretical foundations from sociomateriality and practice theory (Leonardi 2013c; W. J. Orlikowski 2007; Orlikowski and Scott 2008; Pickering 1993). It substantiates a view of distributed agency in digital innovation building on the premise that technological artefacts are continuously enacted through evolving socio-technical practices. As such, it takes into account the fluid and socio-technical nature of digital technologies, as practices are enacted in reciprocal imbrications. However, in practice digital technologies are still studied and conceptualised from the perspective of human actors and therefore remain exogenous to theorising, so that their assessments and accountabilities cannot be clearly located and are considered to be 'inscrutable' (Orlikowski and Scott 2013).

However, each of the three conceptualisations of digital agency rests on an assumption of technology essentially as tools. This assumption results in a failure to adequately explain the emergent characteristics of today's complex and distributed processes of digital innovation. These distributed digital innovation processes have critical characteristics that makes them radically different from previous forms of technological innovation (Yoo et al. 2010). Consequently, deeper conceptualisation of the distributed dynamics of digital innovation as well as new ways of analysing and theorising such processes are required (Hedman et al. 2013; Venturini 2009).

The study presented in this thesis reviews the distributed digital innovation of customer service and reorganisation of the branch network at Barclays, a global bank headquartered in the UK with a history dating back to 1736. It has some 24,000 employees in the UK, about 18,000 of which are working in the branch network consisting of more than 1,600 branch locations. In the wake of the recent financial crisis, Barclays set out to reengage with local communities.

In particular, the use of digital technology for speed, transparency, and accessibility of service delivery was deemed necessary for such an engagement and for re-establishing trust in the industry at large. As a result, Barclays introduced a number of innovative digital services such as ‘talking ATM machines’ to aid visually impaired customers, and advanced online banking services to enable customer transactions. This study follows the emergence of a new mobile information system for frontline staff (i.e. branch personnel) as it went from being a replacement for email and legacy desktop systems to affecting radical digitalisation of frontline services involving reorganisation of the branch network, changing the layout of individual branches, and ultimately reconfiguring the fundamentals of how and where the bank would service their customers.

This thesis explores the agency dynamics by which retail banking at Barclays was radically transformed through distributed small-scale encounters between heterogeneous actors. In doing so, it advances and substantiates a new perspective on agency in distributed digital innovation. It conceptualises how organisational transformations occur through micro-level actions distributed in innovation networks, and applies this lens to an in-depth, two-year, multi-method case study using qualitative analysis, social network analysis and computational content analysis techniques.

The scope of the thesis is to apply new computational methods to explore distributed digital innovation capturing the multiple localised events through which distributed human and material actors engage in innovation activities. This approach has the dual purpose of introducing a new methodological approach to studying distributed innovation processes and substantiating a theoretical conceptualisation of agency dynamics in distributed digital innovation.

In summary, the motivation for this thesis is the inadequacy of extant theoretical perspectives in explaining the agency dynamics that unfold in distributed digital innovation by combining existing research techniques with new computational methods. This allows for a new empirical and conceptual perspective on distributed processes in the context of digitisation and digital innovation. In the following, I will provide a brief overview and definition of key concepts used in the thesis to formulate the problem statement and research questions that guided the study.

1.2 Problem Statement and Research Questions

The previous discussion summarises an understanding of distributed digital innovation as a process in which radical firm level transformations are generated through localised actions involving multiple heterogeneous actors, and relates it to existing streams of research in which the specific agency dynamics involved does not seem to be adequately well understood or explained. Based on this motivation, this section formulates the research questions guiding this research. In order to do so, it must address the following problem resulting from the research motivation:

The digital innovation literature provides powerful accounts of the generative and fluid nature of digital innovation, and the literatures on organisational path dependence and path creation include deep descriptions of the dynamics of digital transformation. Common for both streams of research is that they generally conceptualise digital innovation from the point of view of human designers, managers and users. A single human actor or central group of actors are predominantly cast in the role of the protagonist.

However, applying new computational research methods allows researchers to take the perspective of the digital artefact, the information system, thus revealing evidence to suggest that a new breed of digital technologies, under certain circumstances, invokes a novel and distinct cast of distributed actors, that affect radical organisational transformations. In order to analyse such emergent and distributed digitalisation, the human bias must be mitigated and new perspectives developed. Deep conceptualisation of the agency dynamics by which digitally distributed actions accumulate into radical organisational transformations has so far been deemphasised to the detriment of theoretical, methodological and practice related insights with the potential to guide more reflective digitalisation in business and in society at large. Following from this problem statement, the overarching research question guiding this thesis can be formulated as such:

How do digitally distributed actions lead to radical organisational transformation?

In order to answer the research question, it is necessary to address three sub questions pertaining to 1) the process of organisational transformation through digital innovation, 2) the structure and characteristics of interconnections between distributed agents involved in transformational activities, and 3) the nature of the micro-level actions that combine to affect organisational transformation.

Organisational transformation through digital innovation rarely occurs as a single isolated event, but rather aggregates from multiple instances of distributed agency. This raises the issue of how do transformations involving processes of distributed digital innovation differ from the processes of technological change that are described and theorised in the existing literature on technological trajectories. These issues are addressed in the first sub-question:

Q1: What are the characteristics of digitally enabled organisational transformation?

Following from this first research question the issue of establishing the context and boundaries for the process of distributed digital innovation arises. The second sub question addresses the issue of whom and what are the actors involved in such distributed innovation activities, and how does the structure of their interconnections affect organisational transformation. To this end, it is important to establish how actors are connected through distributed actions and how the structure of such innovation networks affect the process of digital transformation over time. These issues are addressed in the second sub-question:

Q2: How does the distributed structure of digital innovation networks lead to organisational transformation?

The next question to arise concerns the small-scale actions involved in shaping organisational trajectories. Specifically, it is concerned with what is the nature of distributed actions, and what are the dynamics by which such small-scale actions fail or succeed in affecting change to the overall trajectory. Hence the third sub-question is articulated as follows:

Q3: What are the characteristics and dynamics of distributed actions that affect radical organisational transformation?

In combination, the three sub-questions aim at addressing key elements of the overarching research question in such a way as to provide the basis for theorising the agency dynamics of distributed digital innovation. As digitally distributed innovation processes represents a relatively new sociotechnical phenomenon that is by nature embedded in digital technology, it is necessary to also revisit existing research methods. By combining existing analytical and theory building methods with computational data analysis, it is the aim of this thesis to generate a sufficiently granular empirical investigation to generate theory that addresses the stated research questions. I now move on to elaborate and discuss the research objectives and approach taken to address the research questions in more detail.

1.3 Research Objective and Approach

The main objective of this thesis is to undertake an empirical inquiry that describes, explains and deepens existing theorizing and understanding of the agency dynamics that play out in distributed digital innovation. Grover & Lyytinen (2015) identifies the current state of play in IS research as generating mid-level theory by applying existing theoretical concepts from other fields to study information systems by following a conventional schema or 'script'. This approach leaves IS research on a middle ground where researchers neither build grand theory or provide empirical insights at a significantly detailed resolution. They call for research that pushes to the ‘edges’ either by producing either high level theory, or by undertaking extensive as well as intensive inductive empirical analyses. This thesis aims to generate the latter type of inductive ‘edge’ theory through “inductive, rich inquiries using innovative and extensive data sets” (Grover and Lyytinen 2015, p. 1).

The theory that is built in this thesis is a grounded process theory. It is grounded as its concepts and their relations are constructed inductively following the general guidelines for conducting grounded theory research (Glaser and Strauss 1967; Urquhart et al. 2009) and it is a process theory because it explains the temporal progression of a discrete set of events (Langley 1999).

Data was collected over an 18-month period from December 2012 to May 2014 describing several examples of successful as well as unsuccessful events involving innovation activities at multiple distributed locations. Data collection followed the evolution of a radical transformation of retail banking that started with the development of a mobile information system and eventually redefined frontline customer service. This means that data collection, -analysis and theory building took place in several iterations each guided by previous conceptual development. In order to successfully obtain the objective of producing theory, I went through three such iterations of inductively identifying key events and concepts in the digital innovation process, establishing the relations between said concepts, and building theoretical abstractions of the dynamics that drove the process of distributed transformation.

The first iteration pertains to theorising the nature and formation of organisational trajectories of transformational events related to the project in question. This was achieved by describing the multiplicity of transformational events that form a sequence of organisational transformations throughout the case history. Specifically, qualitative interview and document analysis techniques were used to describe the paradigmatic and syntactic dimensions of the innovation process (Latour et al. 1992), i.e. its sequence of progression and the actors and resources mobilised at each step. Special emphasis was given to describing the multiple distributed events that combined into a sequence of episodes involving organisational transformation. The outcome of the first research iteration is to produce a thick description of the case history and the involvement of key actors.

The second iteration establishes the relation between distributed actors and episodes of organisational transformation by analysing the innovation network context in which the multiple distributed events took place. This includes analyses of the role of specific actor types and network structures in affecting organisational transformation over time. This link was established by applying social network analysis of digital trace data related to the case history. The outcome of the second iteration is to produce a substantive theorisation of the relation between the characteristics of actors, the distribution of these actors, and the organisational transformations they affected. The aspiration is to conceptualise the nature of distribution in order to add granularity to existing theories of innovation networks (Dhanarag and Parkhe 2006; Yoo et al. 2008). Specifically, by conceptualising the nature of actors involved in distributed digital innovation as well as the structure of their interactions, this iteration adds to an understanding of how the structure of innovation networks connect distributed events to produce organisational transformation.

The final research iteration is intended to build a deep understanding of the agency dynamics by which distributed small-scale actions affect digital transformations. Computational content analysis (Landauer et al. 1998; Simmons and Zachary 2006) is applied to textual representations of multiple interactions between actors within the innovation network. Literature relating to narrative networks (Pentland and Feldman 2007) and action nets (Czarniawska 2004) is used to identify accounts of agency patterns that shape trajectories of distributed digital innovation.

The theory is confined to describing, explaining and understanding the process by which radical transformations emerged through distributed digital innovation within the specific context at Barclays. Though the theory is constructed in such a way that might be transferrable to other similar contexts, it does not make claim to be exhaustive in terms of the possible explanations of the radical transformation of retail banking at Barclays, as the bank has multiple structural couplings with global financial markets, as well as industry specific, regulatory etc. systems outside the scope of this analysis. However, within the scope laid out above, it does provide significant contributions as discussed in the following section.

1.4 Targets for Contribution

The potential contribution that follows from reaching the research objectives

is to generate new theoretical conceptualisation of the dynamics of agency in distributed digital innovation. The purpose of this theorising is to contribute to the emerging literature on distributed digital innovation (Puranam et al. 2006; Yoo et al. 2012; Yoo et al. 2010) by providing a deep conceptualisation of how new organisational trajectories are formed through multiple digitally distributed actions enabled by digital technology. Specifically, by taking the analytical perspective of the digital artefact, the goal is to contribute to build a new theoretical perspective on digitally distributed innovation processes.

Through rich and inductive inquiry using traditional as well as new methods and techniques I hope, in some small measure, to contribute to new ways of conducting IS research by taking into account the perspective of the IT artefact itself. Combined with the impracticality of relying solely on existing methods to study distributed innovation processes, the complexity of designing and conducting such rich inquiries at multiple locations across organisational and geographical boundaries means it is necessary to employ several methodological approaches involving both traditional qualitative and computational analysis techniques to capture the depth of each localised context as well as the scope of the entire innovation process (Venturini 2012).

The intention is that this will lead to results that can contribute to existing theorising on distributed digital innovation and emerging literature on organising for innovation in the digital age (Puranam et al. 2006; Yoo et al. 2012). By doing so the hope is to be able to inform business decisions regarding design, implementation and management of distributed digital innovation in practice. The expected contribution includes both a deep and operational understanding and conceptualisation of where and how digitalisation and digital innovation evolves, and specific methods and techniques to generate actionably metrics and analytics to directly inform day-to-day business decisions.

1.5 Structure of the Thesis

Directly following this introductory chapter, chapter 2 reviews the literature on distributed digital innovation, organisational transformation, distributed agency and innovation networks to establish the conceptual and theoretical reference to which the research aims to contribute.

Based on the literature review, chapter 3 presents the philosophical foundations for the research and introduces the grounded computational analysis approach guiding the empirical study. Chapter 4 describes the reflections underlying the choice of empirical setting and presents the research design that was implemented in the case study. It also details the mixed-methods data collection and analysis techniques applied in the empirical study.

Chapter 5 presents the empirical analyses of the case relating to each research of the three research sub-questions, and outlines the important theoretical findings of each analysis before they are discussed in chapter 6 as a basis for developing theoretical development and contributions of the thesis.

Methodological implications of the thesis and reflections on their linkage to the theory building is presented in chapter 7. Finally, conclusions are drawn in chapter 8 before the thesis ends with reflections on possible venues of further research.

2. LITERATURE REVIEW

This chapter reviews existing literature on distributed digital innovation, organisational transformations, distributed agency and innovation networks to establish a fundamental understanding of key concepts related to the research question. First, it reviews the digital innovation literature and identifies a gap in received theory on the relation between the general properties of digital innovations and the agency dynamics through which they are shaped.

In reviewing this literature, three dimensions of distributed digital innovation, each relating to distribution of a specific organisational entity, are identified. Next, it reviews the technological trajectories literature to provide a general understanding of how different theoretical streams conceptualise technological transformation processes. Finally, it reviews literature on innovation networks to provide an understanding of how digital transformations emerge through the micro-level actions of interconnected actors.

Following on from this, table 1 summarises key concepts that are introduced in this chapter, and that play an essential part in this thesis. While each of these concepts are defined in greater detail in the relevant literature review sections, they are presented here to provide an overview of the conceptual framework of the thesis. As a result, some of the definitions given here are simplified, and they will be extended and elaborated in the appropriate discussion of the literature.

Table 1. Key Concepts Used in the Thesis		
Concept	**Definition**	**Example References**
Digital technology	A technology whose core architecture is based on the processing of digital data in a modular layered infrastructure	Henderson and Clark (1990) Baldwin and Clark (1997) Henfridsson et al. (2007) Yoo et al. (2012) Kallinikos et al. (2013)
Digital innovation	The waves of related innovation practices that follow the digitisation of physical artefacts	Boland et al. (2007) Zammuto et al. (2007) Henfridsson et al. (2009) Svahn et al. (2009) Yoo et al. 2010
Technological trajectory	The course of organisational and technological evolution to which lock-in occurs over time	Arthur 1989 Garud and Karnøe, 2001 Schreuogg and Sydow 2009 Vergne and Durand (2011)
Digital trajectory	A technological trajectory whose core architecture is based primarily on digital technology	Lyytinnen and Rose (2003) Henfridsson and Yoo, (2013)
Organisational transformation	A shift in dominance from an incumbent to an emerging technological trajectory resulting in changes in at least one of three dimensions of digital innovation: artefact, cognitive, and control	Garud and Rappa (1994) Geels (2004; 2005) Svahn et al. (2009) Henfridsson and Yoo (2014)
Innovation network	A network of distributed actors connected through participation in innovation activities	Yoo et al. (2008) Yoo et al. (2010)
Distributed agency	The enactment by a network of material and/or human actants of a change in the course of action of at least one other actant	Garud and Karnøe (2003) Garud et al. (2007) Yoo (2010) Latour (2014)
Micro-level action	The pairing of a digitally mediated action and at least one actant	Czarniawska (2004) Pentland and Feldman (2007)

Next, I move on to review and connect each of the key concepts to provide a fundamental conceptual understanding of the object of interest for this research.

2.1 What is Distributed Digital Innovation?

Recently emerging literature on distributed digital innovation views radical digital transformation as a process by which dispersed actions distributed across an innovation context (e.g., an organisation) collectively have the potential to create new radical transformations (Puranam et al. 2006; Yoo et al. 2010). This section first reviews the literature on digital innovation to establish key characteristics of digital transformation and on that foundation, reviews the various conceptualisations of distributed digital innovation found in existing literature. The aim is to provide a conceptual understanding of digital innovation processes in general, and specifically of the ways in which these processes are distributed.

Digital technology based on a layered modular architecture facilitates innovation of services and products with radical organisational consequences (Kallinikos et al. 2013; Lusch and Nambisan 2015; Nambisan 2013). The novel design principle of layered modular architecture means that, in the context of digital technology, new service, content and organisational innovations are agnostic of the physical infrastructure and devices used to transmit and process digital data (Yoo et al. 2010).

This freedom of recombination across layers means that a plethora of new innovations can emerge through the numerous possible reconfigurations of social and technological structures (Henderson and Clark 1990; Henfridsson et al. 2009; Suchman 2007). Extant research identifies three topics of specific concern to digital innovation, which have not yet been fully understood; the modularity and fluidity of digital artefacts, the transition to digital platforms, and the distribution of innovation activities (Bailey et al. 2011; Yoo et al. 2012).

First, with the adoption of digital technology based on the layered modular architecture in organisations, new types of innovation emerge involving transformations of product and service architectures and organisational transformations (Baldwin and Clark 2000, 1997). Commonly shared notions of modularity include that it facilitates fluidity in complex information systems thereby introducing an increasing level of uncertainty (Baldwin and Clark 2000). Pivotal to the idea of modular systems design is the principle of loose coupling between components in the system leading simultaneously to interdependence within, and independence across various components (Baldwin and Clark 1997; Henfridsson et al. 2009). Such loose couplings allow for the distribution of innovation in several dimensions, which will be further explored in subsequent sections (Yoo et al. 2008).

This notion of loosely coupled components is foundational to digital innovation. Components have in various streams of research been conceptualised as parts, patterns, or platforms (Alexander 2006; Baldwin and Clark 2000; Pohl et al. 2005). For example, the product innovation literature predominantly views components as physical parts and focuses research attention to how components are decomposed and aggregated (Baldwin and Clark 2000; Ulrich 1995). The underlying assumption of this focus on decomposition and aggregation is a *"part-whole relationship where parts are associated with the whole through many-to-one relationships in hierarchical architectures"* (Henfridsson et al. 2009, p. 3).

However, the layered modular architecture of digital innovations means that components are loosely coupled in multiple design hierarchies at multiple layers representing a radically new organising logic (Henfridsson et al. 2009; Yoo et al.

2010). Digital architectures comprise of device, network, service, and content layers, each agnostic to the materiality of components belonging to other layers (Henfridsson et al. 2009). This freedom of component configuration leads to a fluidity of technological boundaries and meanings with severe managerial and strategic consequences for the organisation of corporate IT platforms.

The result is emergent and even 'accidental' innovations (Austin et al. 2011) that fall in two categories identified by Henderson and Clark (1990): modular and architectural innovations. Modular innovation can happen when a core design concept changes without affecting the components of the end product. Examples include the replacement of an analogue TV signal a digital one or the replacement of analogue phones with digital devices. In architectural innovation, the linkages between core components and concepts are changed while maintaining concepts and components. Architectural recombination of design components can be triggered by a change in a component or the introduction of a new component to the platform e.g. when mobile devices are used in the workplace. Considering the multi-layered architecture of digital innovations, corporate IT processes are increasingly complex with managerial and strategic implications on the organisational level (Baldwin and Clark 2000, 1997; Garud et al. 2008; Henderson and Clark 1990).

Secondly, the move from technical artefacts to digital platforms opens the firm to external innovations (Boudreau 2012; Gawer 2009). While the concept of digital platforms is not new to organisation science (Ciborra 1996; Kim and Kogut 1996), resent research points out that the proliferation and penetration of digital technology in organisations have increased dramatically in recent years (Yoo et al.

2012). Consequently, two key attributes of digital platforms are defined as convergence of previously separate technologies, and generativity in enabling innovation of new services and technologies. Technological convergence means organisations increasingly innovate by creating platforms comprising of an ecosystem of layered modules, e.g. like those of the Google apps platform, rather than discrete and singular products, like ERP systems or traditional intranets. Generativity of new products and services refers to the ways in which corporate digital platforms can serve as a infrastructures on which other services and products can be built by a wide variety of actors within the organisation (Yoo et al. 2012).

Finally, control and access to innovation is distributed from a centralised group of entrepreneurs, typically managers or designers, to involve a wider circle of actors at the periphery of the organisation. Recent literature on distributed innovation networks has shown how heterogeneity of knowledge resources and distribution of control and coordination has facilitated new forms of digital innovation (Dhanarag and Parkhe 2006; Yoo et al. 2008).

Some research has taken a purely structural perspective of innovation networks, largely ignoring the agency of individual actors (Gloor et al. 2008; Peng and Mu 2011), while other research efforts have focused on individual actors and not emphasised the structural properties of their interconnections (Swan et al. 1999). Despite the differences in perspective, both streams of research investigate how new populations of actors engage in distributed digital innovation.

Combining both structural and subjective perspectives on innovation networks, Yoo et al. (2008) identifies four types of innovation networks delimited by the degree to which they involve distribution of coordination and control, and heterogeneity knowledge resources. This research suggest that distribution of coordination and control occurs when previously unconnected actors are brought together through new technology. Through the double distribution of both access to heterogeneous knowledge resources and control and coordination of the innovation process, digital innovation networks emerge as ‘doubly distributed’ (Yoo et al. 2008, p. 5). The emergence of doubly distributed innovation networks has strategic consequences for the management of innovation processes, where orchestration of relations and distributed activities in innovation networks replaces traditional command and control structures (Dhanarag and Parkhe 2006; Zachariadis et al. 2013).

However, this definition of doubly distributed networks does not include the distribution of digital artefacts themselves through modular layered architecture though it is taken as a precondition. This effectively adds a third dimension of distribution involving the distribution of digital infrastructures and technology (Kallinikos et al. 2013; Lindgren et al. 2008).

Following from this, the literature on distributed digital innovation reveals at least three conceptual dimensions describing specific elements of the distributed nature of digital innovation; distribution of access to artefact innovation, distribution of competencies and knowledge resources, and distribution of organisational control structures (see table 2 for summary).

Each of these three dimensions of distributed digital innovation builds on varying streams of research to arrive at different yet complimentary definitions of distributed digital innovation as showed in table 2. Research on the technology dimension emphasises how the materiality of digital artefacts enable greater access to modification (Baldwin and Clark 2000; Yoo et al. 2012).

Views represented in the knowledge dimension explore how the range of skills and competencies needed to innovate lead to a more diverse, and therefore also dispersed, knowledge resources leveraged by a distributed cast of actors (Boland et al. 2007; Boudreau 2012; Lakhani and Panetta 2007). Finally, the perspective of research in the organisational control dimension focuses on how the introduction of digital technology shifts the locus of control of innovation processes from a centralised hierarchy to a distributed network of heterogeneous stakeholders (Eaton et al. 2015; Hanseth and Lyytinen 2010; Tilson et al. 2010).

Table 2. Dimensions of Distributed Digital Innovation

Dimension	Foundational Literature	Definition of Distributed Digital Innovation	Example References
Distribution of digital technology and access to innovation	• Design science • IT architecture	The process by which multiple actors use the lowered entry barriers to digital technology to develop new designs	Henderson and Clark (1990) Baldwin and Clark (2000) Henfridsson et al. (2007) Yoo et al. (2010) Yoo et al. (2012) Kallinikos et al. (2013)
Distribution of competences and knowledge resources	• Knowledge management • Entrepreneurship	The process by which multiple human actors with heterogeneous competences collaborate to create new digital innovations	Boland et al. (2007) Van de Ven (2005) Boudreau (2012) Garud and Karnøe (2003) Lakhani and Panetta (2007)
Distribution of organisational control structures	• Innovation strategy • Complexity theory • Digital platform innovation	A complex undertaking where multiple actors' attempts to master their innovation environment will be situated at the intersection between far-reaching global technology and local needs of adaptation to contextual conditions	Braa et al. (2007) Hanseth and Lyytinen (2010) Henfridsson and Bygstad (2013) Tilson et al. (2010) Eaton et al. (2015) Yoo et al. (2008)

Based on the preliminary definitions of the three dimensions of distributed digital innovation outlined in table 2, the following sections review and unfolded each dimension in greater detail.

2.1.1 Distribution of Digital Technology

The technology dimension of distributed digital innovation involves research that conceptualises the distribution of access to participation in innovation practices to a larger group of actors, due to the malleable and generative nature of digital technology (Kallinikos et al. 2013; Yoo et al. 2010; Yoo et al. 2012). This research shows how distributed digital technology embodying a shift from singular artefacts to modular digital platforms, leads to fluid organisational boundaries that open the organisation to peripheral and even external innovations (Baldwin and Clark 2000, 1997; Gawer 2009).

Technology views are typically grounded in research on systems design emphasising the layered modular nature of digital technology, and how this affects the organising logic of innovation (Benkler 2006; Yoo et al. 2010). From this perspective digital technologies are distributed by design in that they are based on a layered modular architecture comprising of device, network, service, and content layers where new innovations are agnostic of physical infrastructure and devices (Yoo et al. 2010).

The layered modular architecture of digital artefacts means that their constituent parts are loosely coupled across the different layers and multiple design hierarchies. Therefore digital technologies as an integral characteristic of their architecture span geographical and organisational boundaries (see e.g. Barrett et al. 2011; Eaton et al. 2015; Lindgren et al. 2008).

Such distributed digital technology means that products and services are increasingly implemented as digital platforms. While the concept of digital platforms is not new (Ciborra 1996, Kim and Kogut 1996), the proliferation and penetration of digital technology in organisations has increased dramatically in recent years (Yoo et al. 2012). A digital platform is defined as a foundation upon which distributed actors "*…can develop complementary products, technologies or services"* (Gawer 2009, p. 2).

Two main attributes of digital platforms are convergence of previously separate services, and generativity in enabling innovation of new services by a larger network of distributed actors (Yoo et al. 2012). The result is that digital platforms serve as a foundation on which other services and products can be built or integrated by a variety of heterogeneous actors across the organisation.

This means that innovation now takes place at both architectural (Henderson and Clark 1990) and modular (Baldwin and Clark 2000) levels. Changes at the architectural level enables innovation of and interconnections between various types of modules to achieve organisational-level objectives related to e.g. governance (Tiwana et al. 2010) or knowledge sharing within and beyond the organisation (Andersson et al. 2008).

Changes in a product component or the introduction of a new module to a digital platform involves innovation of specific entities within the loosely coupled system, that are logically distinct (Henfridsson et al. 2009). Such changes to specific modules can trigger wakes of architectural reconfiguration as they in turn affect the connections between elements within the entire system of components (Boland et al. 2007). Given the layered modular architecture of digital innovations, the process of modular innovation becomes increasingly complex as fixed design hierarchies increasingly give way to loosely coupled component networks with vast numbers of possible interconnections between modules (Baldwin and Clark 2000, 1997; Garud et al. 2008; Henderson and Clark 1990). This increase in complexity can sometimes result in emergent innovations (Austin et al. 2011), resulting from distributed innovations across a distributed artefact .

An important result of this change from rigid design hierarchies in physical products to loosely coupled layered modular networks involving digital artefacts has significantly lowered entry barriers for participation in digital innovation in terms of cheaper and more ubiquitous innovation tools (e.g. you can create digital services from an ordinary laptop), and faster learning cycles as producing, reproducing and testing new innovations can be done at a much faster rate than is the case with analogue or mechanical technologies. For instance, Yoo et al. (2010) associate the layered modular architecture of digital technology with significant distribution of innovation activities by emphasising how the separation of services and devices in multiple layers facilitates the development of a multitude of services at the local level on top of standardised platforms.

In addition, the relative independence of content and network (Yoo et al. 2010) enables the use of multiple types of contents on the same network and the distribution of specific content across multiple technological networks. Consequently, distributed digital innovation involves multiple actors that leverage the lowered entry barriers and layered modular architecture of digital technology to develop new locally bound services distributed across organisational and technological boundaries. Taken together, the layered architecture and low barriers of access to innovation of digital technology entails a potential for wide variety of distributed innovation outcomes with the potential to collectively combine to create momentum for specific organisational transformations.

2.1.2 Distribution of Knowledge Resources

Views represented in the knowledge dimension emphasise the distribution of the multiple skills and competencies that are invoked as a result of lowered barriers of access to digital innovation due to the distribution of digital technology. Knowledge views focus on the way in which new digitally enabled knowledge leads to the emergence of innovation across organisational and disciplinary boundaries (Boland et al. 2007). This increased access to architectural knowledge and need for contextual knowledge in digital technology means that digital innovation often entails a multitude of competences (Latour 1987; Van de Ven 2005; Yoo et al. 2005), where the constant meeting and surfacing of heterogeneous and localised ideas may, or may not, emerge as lasting and significant transformations at the organisational level.

The vast architectural as well as contextual knowledge needed to produce such innovations means that the extent of competences necessary for successful digital innovation far exceeds what a single actor may possess. Collaboration is therefore a prerequisite for distributed digital innovation, as it must involve different forms of competencies and skills (Boudreau 2012; Garud and Karnøe 2003; Lakhani and Panetta 2007). In one empirical study Boland et al. (2007) explored the cascading nature of multiple innovation practices among heterogeneous actors, where the competencies and ideas of individual actors often collide with other innovations, resulting in unpredictable wakes of innovation spreading throughout complex actor networks.

Recent literature on distributed innovation networks develops conceptualisations of distributed innovation showing how heterogeneity of knowledge recourses works in combination with distribution of coordination control, thus leading to new forms of generative digital innovation (Dhanarag and Parkhe 2006; Yoo et al. 2008).

2.1.3 Distribution of Organisational Control

The control dimension focuses on the distribution of organisational control structures pertaining to the process of digital innovation. By involving a multitude of actors connected through a digital infrastructure, digital innovation creates obvious managerial issues as command and control that was traditionally the domain of top management, is now distributed to a heterogeneous network of multiple actors engaging in innovation practices that potentially involve deviating from existing technological and institutional rules and adapting new visions to local contexts (Hardy and Maguire 2008; Leca and Naccache 2006). This means that digital innovation, to a varying extent, supplements command and control structures with coordination dynamics of actor-structure duality in innovation networks (Dhanarag and Parkhe 2006).

The control view implies that actors taking part in digital innovation are necessarily distributed, because the possibility of controlling the path of the general trajectory is highly limited. Traditionally, this view of distributed digital innovation is grounded in complexity theory (Holland 1995; Mol and Law 2002), and sees digital innovation as a complex process where multiple localised actors connected through digital infrastructures are continuously shaping their own environments by adapting to changes in contextual conditions (Braa et al. 2007).

Since all forms of digital innovation to some extent involve already existing infrastructures (e.g. binary code, network protocol, server infrastructure), control views assume that no singular actor controls the innovation process (Hanseth and Lyytinen 2010). Even in cases with powerful platform owners, control is to some extent distributed when third party entrepreneurs tune services to enact specific localised agendas within the context of existing infrastructures (Eaton et al. 2014).

Each of the three views on distributed digital innovation reviewed in this section represent a distinct dimension in which innovation outcomes in the form of local and organisational transformations are generated. The next section reviews theoretical conceptualisations of such organisational transformations related to distributed digital innovation.

2.2 Organisational Transformation

The constant changes to digital technologies to adapt to specific circumstances of distributed contexts sometimes combine to create radical innovations that transform organisational structures. Such radical technological transformations have been conceptualised through a theoretical tradition building on the works of Michael Schumpeter (1942).

Existing research on technological transformation views innovations on a scale from incremental changes to existing components to radical architectural change (Carlo et al. 2012; Dijk et al. 2011; Ettlie et al. 1984; Godoe 2000). Incremental innovation involves operationalisation of localised component knowledge to optimise the performance of each component where radical transformation entails the breaking down and reinvention of existing technological architecture producing changes to technological constraints, knowledge practices and organisational structure (Ettlie et al. 1984).

However, such incremental and radical changes do not appear out of context. Micro-level innovations can potentially combine to affect changes at organisational and industry levels (Geels 2002). Emergence of such radical transformations from micro-level changes appear as a part of a process that unfolds at several co-evolving layers of magnitude depending on the scope of transformation they produce (Geels 2005). These processes of emerging trajectories have been conceptualised as path dependence (Ruttan 1997; Sydow et al. 2009; Vergne and Durand 2010), path creation (Garud and Karnoe 2001; Henfridsson et al. 2009; Karnøe and Garud 2012) and path constitution (Meyer and Schubert 2007; Singh and Mathiassen 2015).

As a main focus of this thesis is on describing the creation of a new trajectory of organisational transformation through distributed digital innovation, the conceptualisation of trajectories presented here builds on a review of prior research concerned with technological trajectories including literature on path dependence, path creation, and path constitution.

The following section provides a conceptualisation of the nature of organisational transformation by reviewing the literature on technological trajectories. Subsequent sections of this chapter focus on how path dependent technological trajectories shift and evolve, and finally the processes by which agents create such new trajectories are examined. Consequently, these concepts are introduced and related in order to build an understanding of the nature of trajectories of organisational transformation and the agency by which they are shaped.

2.2.1 Technological Trajectories

The notion that technological and organisational change follows a historically constrained trajectory is not a new one in the social sciences (Dosi 1982; Nelson and Winter 1977; Perez 1983). Technological trajectories have been conceptualised as: *"…the path of improvements taken by that [emerging] technology, given technologist's perception of opportunities, and the market and other evaluation mechanisms that determined what kind of improvements would be profitable."* (Dosi and Nelson 1994, p. 335).

This concept of technological trajectories as strings of events that follow a linear and progressive path guided and constrained by certain macro-level evaluation mechanisms builds on theories from evolutionary economics (Nelson and Winter 1982; Ruttan 1997; Schumpeter 1942). Despite the common ancestry, rivalry between subsequent theories emphasising revolutionary versus evolutionary aspects of technological trajectories persists (Garud et al. 2010; Vergne and Durand 2011). The inclusion of both perspectives as complimentary in this thesis has the purpose of building an understanding of different facets of distributed trajectory-shaping where multiple distributed micro-level interactions serve as the arena for distributed innovation and organisational transformation.

Moreover, these different theoretical perspectives on trajectories of technological and organisational change share the notion that 'history matters' (Garud and Karnøe 2001; Nelson and Winter 1982). The historical perspective has been applied in studies of evolving trajectories of industries (Simmie 2012), nations (Schienstock 2007), institutions (Alexander 2001), technologies (Thrane et al. 2010), and organisations (Singh and Mathiassen 2015; Sydow et al. 2009) in empirical setting rather than, as is the case with neo-classical models, mostly hypothetical settings (Gartland 2005; Meyer and Schubert 2007).

So far, at least four theoretical approaches to understanding the evolution of technological trajectories have emerged; Darwinian inspired biological analogy, complex adaptive systems theory, co-evolution of technology and institutions, and path dependence and creation theory (Simmie 2012). These complementary approaches to conceptualising technological transformations in various ways see technological trajectories as progressing through a balancing of revolution or evolution.

Paradoxically, both explanations related to evolution and revolution respectively are for most part attributed to the work of Joseph Schumpeter (Schumpeter 1942) some seventy years ago. Based on Schumpeter's notion of 'creative destruction', revolutionary explanations emphasise the genius of the entrepreneur whose character allows him to imagine new innovations and strive to realise his visions (Abernathy and Clark 1993; Grand and MacLean 2003). In contrast, evolutionary explanations focus on the idea that technological and organisational change follows a historically constrained trajectory (Dosi 1982; Nelson and Winter 1977; Perez 1983).

As the objective of this thesis is to theorise the distributed agency dynamics of digital innovation processes, description of revolutionary radical transformations affected by a single actor or actor group is not within the scope of the thesis. The aim is to show how incremental micro-level innovation can lead to radical organisational outcomes. Consequently, trajectories are conceptualised through an evolutionary lens at the micro-level to explain how radical transformations can occur at the organisational level. To this end it is useful to first distinguish the different theoretical scopes of the most important conceptualisations of technological trajectories.

Table 3 shows how different theories conceptualise technological trajectories at different empirical levels. Traditional path dependence theory has mainly been applied to study large-scale transformations at the national or industry level. This perspective has been developed into an organisational theory of path constitution drawing on both structural historical explanations as well as accounts of the agency of individual stakeholders. Finally, path creation views are mainly applied to account for such agency as performed by specific actors or constellations of actors connected in sociotechnical networks.

Table 3. Theoretical Scopes of Technological Trajectories

Analytical level	Base literature	Key concepts	Reference examples
Industry or national level	Evolutionary economics	Path dependence Lock-in Technological regimes	Nelson and Winther, 1977 Dosi, 1982 David, 1985 Arthur, 1988 Vergne and Durand 2010
Organisational level	Organisation theory	Path constitution Niche innovation Landscape Episode	Sydow et al. (2009) Petermann et al. (2012) Breznitz (2009) Singh and Mathiassen (2015) Geels (2004)
Innovation network or actor level	Actor Network Theory	Path creation Distributed agency Bricolage	Garud and Karnøe (2001; 2002; 2005) Henfridsson and Yoo (2013)

At the industry or national level, technological trajectories are seen as explanations for the evolution of economic systems based on the assumption that that any meaningful study of such processes must be found in an account of its historical context (Gartland 2005; Schumpeter 1942). The historical dependency of technological trajectories is a triple dependency where the progression of events is dependent on the path of past events, each event is dependent on the preceding event, and the outcome depends on the whole sequence (Breznitz 2009). Such path dependent trajectories are characterised by being non-ergodic meaning that a path dependent trajectory depends on its own history in a non-linear, contingent way allowing for several possible outcomes (Arthur 1988; David 1985). As a result path dependent trajectories are unpredictable and display complex or chaotic dynamics (Baum & Silverman 2001).

Applying this concept of path dependent technological trajectories at the organisational level, Sydow et al. (2009) divides the process of organisational path dependence into three phases: the preformation phase, the formation phase, and the lock-in phase. The preformation phase is characterized by a broad scope of possibilities and high complexity of choice, as a trajectory has still not materialised. As increasing constraints created through alignment of distributed actions reduce the number of possible outcomes, the system reaches a critical juncture as a trajectory starts to take form. In the formation phase self-reinforcing mechanisms impose ever-stronger constraints increasingly narrowing the path until all alternatives are eliminated and lock-in occurs as a radical transformation is established within the organisation (Sydow et al. 2009).

A major critique against the path dependence perspective is that a state of lock-in is contingent upon the absence of external shock and is only achieved in fully autonomous systems (of which there are very few in society). For most path dependent processes, the contingence condition introduces difficulties in defining the scope of the system.

This has led to some tension within path dependence literature as tension between emphases on either a generalizable structural explanation of high-level trajectories on the one hand, and on the other hand accounts of situated agency enacted within a specific practice context on the other hand. In other words, explanations of technological trajectories relate to either the *"…historical ideographic ideal emphasizing the uniqueness of each historical moment or the social scientific nomothetic ideals emphasizing theoretical generalization*" (Stråth 2009, p. 21).

Reconciliation of these different theoretical perspectives have sought to mitigate the assumptions of path dependence theory that a) actors behave rationally, b) transformation is exclusively the result of emergent processes and cannot happen as a consequence of deliberate planning or mindful action, and c) once a trajectory in locked in, only external shock can unlock it (Meyer and Schubert 2007).

The resulting path constitution views point out that lock-in should not be seen as a final stage in a linear process but rather as a context of innovation practice that is temporary and continuously acted upon and un-locked through the actions of organisational actors at the micro-level (Singh and Mathiassen 2015). This research suggests that technological changes that manifest as organisation-level transformations are continuously shaped through micro-level interactions between distributed actors. This conceptualisation builds on the notion of embeddedness of technological systems where artefacts continuously shape and are shaped by their organisational and institutional context (Garud et al. 2007; Garud and Jain 1996; MacLean 2001). The following section explores the ways in which such technological embeddedness means that localised technological changes involving digital technology can affect radical shifts at the organisational level.

2.2.*2* Trajectory Shifts

Shifts in technological trajectories have been conceptualised in path dependence in a ´weak' version of path dependence that simply takes path dependency to mean that 'history matters' in any context involving technological or organisational change, and a 'strong' version that focuses on the effects of amplification of small initial differences in causing radical outcomes (Garud and Karnøe 2001; Magnusson and Ottosson 2009). The latter focus on identifying self-reinforcing mechanisms that forms paths of transformation leading to technological and organisational lock-in (David 1985).

More recent research on trajectory shifts in institutional entrepreneurship (Henfridsson and Yoo 2013) and digital infrastructures (Henfridsson and Bygstad 2013) conceptualises the mechanisms by which technological trajectories shift through liminal periods of transition. Such liminal moments of transformation have been described as going through a cycle of novelty, confirmation and transformation where transformational potential is determined by the ability of actors to produce novel propositions and ideas and subsequently confirm its value to the actors involved (Carlile and Lakhani 2011).

These liminal events leading to micro-level change determine the changing technological possibilities that emerge into organisation level transformations. These emergent trajectory shifts represent paradigms of 'technological regimes' (Breschi et al. 2000; Castellacci 2008; Godoe 2000; Svahn et al. 2009). Drawing inspiration from Kuhn's thinking on scientific paradigms (Kuhn 1962) innovation trajectory shifts are thus seen as a successive series of shifts in technological regimes (Dosi 1982).

Consequently, by creating the potential for novelty to be proposed at the micro-level, the inefficiencies of an incumbent technological regime create the conditions for challenging dominant logics through adaptation of technological and organisational structures at the micro-level (Nelson and Winter 1982, 1977). When existing technological and organisational structures change, tensions arise due to conflicting regimes and *"…the linkages in the configuration 'loosen up'"* (Geels 2002, p. 1272).

In other words, the structure of the dominant technological regime 'warms' (Callon 1986; Geels 2005), and reconfigurations brought on by emerging regimes are likely to follow as a result of new innovations. Such reconfiguration results in the emergence of paradigms of new technologies, meanings and control structures through tussles between actors representing incumbent and emergent regimes (Gupta et al. 2006; Tilson et al. 2010). In order to provide a background for understanding the context of such distributed interactions, the next section unfolds in greater detail the different ways in which trajectory shifts have been associated with controversy.

2.2.3 Transformation as Controversy

Multiple theoretical perspectives in various ways and at different analytical levels each emphasise controversy as a key driver in the shaping of technological trajectories. Specifically, three distinct theoretical views conceptualise innovation as controversy. I will refer to these perspectives by their analytical focus as; technological trajectories, situated enactment, and innovation network. Table 4 shows an overview of how each of the three theoretical perspectives conceptualise different aspects of controversy as a driver for shaping technological trajectories.

Table 4. Conceptualisations of Controversy

Conceptual elements	Technological trajectories	Situated enactment	Innovation network
Theoretical foundations	Evolutionary economics Path dependence	Sociomateriality Practice theory	Actor Network Theory Path creation
Conceptualisation of tension	Clashing dominant and emerging technological regimes mediated by external selection mechanisms	Resistance and accommodation in mangle of practice	Controversy between actants with conflicting agendas distributed over complex innovation networks
Contestation	Emergence	Resistance	Mindful deviation
Outcome	Lock-in	Accommodation	Actor network reconfiguration
References	Winther (1982) Dosi and Nelson (1984)	Pickering (1993) Leonardi (2013)	Callon (1981) Latour (1992) Garud and Karnøe (2001) Venturini and Latour (2009)
Material agency	Constraints to human agency, which emerge through external mechanisms	Practice of interacting with artefacts	A semiotic actant rather than a physical entity

The technological trajectory perspective mainly conceptualises technological change at the level of industries and countries. This macro perspective entails a generic understanding of trajectory shaping as a clash of conflicting regimes or paradigms (Castellacci 2008; Godoe 2000). Consequently, the technological trajectories perspective places little emphasis on the agency of specific actors and as actors are seen as a homogenous population of agents constrained by systemic mechanisms (Vergne and Durand 2010, 2011). The technological trajectories perspective therefore sees controversy as tensions between paradigms involving conflicting sets of macro-level mechanisms.

Recently emerging research emphasises controversy as a driver for digital innovation from what could be referred to as a the situated enactment perspective (Eaton et al. 2015; Leonardi 2013a; Orlikowski and Scott 2008). This perspective sees innovation as a set of practices enacted in sociotechnical systems whereby trajectories are shaped in a constant dialectic of accommodation and resistance between human and technological actors. Though the situated enactment perspective allows for analysis of specific affordances of distributed digital technologies, it is to a large extent confined to the context of observable practices within a given empirical context. Despite recent attempts at a more generalizable theory based on sociomateriality (Gaskin et al. 2014) the emphasis on situated practice makes it difficult to apply the sociomateriality in building a generalizable theoretical framework for distributed digital innovation.

To this end, the innovation network perspective provides a theoretical lens that lets the researcher freely zoom in and out from the macro to micro level as branching trajectories of distributed innovation are continuously created (Garud et al. 2010; Latour 2011, 2014). This notion is inspired by ideas proposed by Michel Callon (1986), and later developed by Bijker and Law (1992), that trajectories emerge as a consequence of changing actor network compositions. In a study of the trajectory of the development of the TRS2 fighter jet in the UK, Law and Callon show how technologies are continuously shaped and translated through controversy between heterogeneous localised stakeholders, and how this technological trajectory is reshaping organisational boundaries by decomposing stable actor relations and coagulating loose networks to form new organisational structures (Law and Callon 1992).

Agency leading to such changes to innovation paths typically emerge across organisational and disciplinary boundaries (Boland et al. 2007; Lindgren et al. 2008) and relies on the constant meeting and surfacing of heterogeneous and localised ideas, needs and agendas that, under certain conditions, emerge as lasting and significant transformations at the organisational level. Transformation is therefore configured through collisions between the paths of actors belonging to different localised micro-networks (Jay 2013; Linde et al. 2003; Smith and Lewis 2011). Such collisions occur as a result of mindful deviation from existing procedures, rules and conventions by actors who leverage the opportunities that the technology of a new paradigm offers (Schienstock 2007).

For instance, as actors actively seek to shift the current innovation path by enacting their own agendas within the scope of their local network (Garud and Karnøe 2001), this may counter-act the actions taken by actors of another network location. These attempts to shift local paths spur controversies as they collide with other micro-level networks with diverging and potentially conflicting intentions and visions (Callon 1981; Latour 1991a; Venturini 2009, 2012).

While all three perspectives provide strong accounts of the shaping of technological and organisational trajectories, the technological trajectory literature focuses entirely on the trajectory level transformation leaving little room to conceptualise micro-level agency. In contrast, the situated enactment perspective provides a strong lens for investigating specific micro-level practices situated in specific contexts, but makes it difficult to study the distributed patterns of such micro-level action that lead to organisational transformation. The innovation network perspective offers a way to conceptualise such patterns of distributed agency that is suitable for studying agency dynamics in distributed digital innovation, but makes it difficult to establish the process of organisational transformation that is affected through such patterns.

To further understand the distributed process of digital transformation, this research combines elements of the technological trajectories and innovation network perspectives to theorise how micro-level controversies, understood as a liminal moment when the shaping of a digital technology reenergises and endangers established actor relationships, combine to affect organisational transformation at the trajectory level.

On this backdrop the following section reviews existing research conceptualising such micro-level agency of distributed actors to provide a fundamental understanding of the agency that leads to organisational transformation through distributed digital innovation.

2.3 Micro-level Agency Dynamics

As a consequence of the notion of distributed digital innovation presented in previous sections, distributed agency in digital innovation can be defined as locally bounded interactions resulting in organisational transformation in terms of a) changes to technological structures, b) changes to knowledge resources and practices, and c) distribution of organisational control structures (Garud and Rappa 1994; Henfridsson and Yoo 2014). Such radical digital transformations happen as a consequence of multiple distributed actions taking place in localised networks of heterogeneous actors with the potential to transform technological, knowledge related and organisational structures over time (Henfridsson et al. 2009; Garud & Karnøe 2001).

Such distributed agency is enacted in arrangements of interwoven negotiations, or 'agencements', involving multiple interconnected agentic orientations and actors across the organisation (Callon 2005; Garud et al. 2011). This definition of distributed agency implies a shift the locus of innovation from stable relations between individual actors to localised negotiations, or controversies, that continuously balance out conflicting organisational forces within distributed actor networks (Linde et al. 2003). This section first reviews existing literature on distributed agency and on that foundation, moves on to conceptualise the micro-level actions carried out by distributed actors.

2.3.1 Distributed Agency

The question of how agency is attributed to either individual actors or distributed innovation systems has been subject to significant theoretical disputes (Garud et al. 2010; Vergne and Durand 2010). This theoretical incongruence illustrates the need for theory that combines both views in a granular yet generalizable conceptualisation of the ways in which micro-level agency enacted by distributed actors affect systemic transformation. The following section addresses this issue by, based on exiting research, defining the notion of distributed agency adopted in this thesis.

The agency of distributed actors or groups of agents at the micro-level plays a pivotal role in the emergence of organisational transformations that make up technological trajectories (Garud and Karnøe 2001; Henfridsson, Yoo, et al. 2009). This process of path creation in micro-level networks of actors has been termed 'bricolage' (Garud and Karnøe 2003; Latour 1996). Garud and Karnøe describe bricolage as: *"…a process of moving ahead on the basis of inputs from actors who possess local knowledge, but through their interactions, are able to gradually transform emerging paths to higher degrees of functionality"* (Garud and Karnøe 2003, p. 296).

Following from this, distributed agency can be defined as the distributed actions by which heterogeneous actors in response to localised needs and events, mindfully contribute to a steady accumulation of artefacts, tools, practices, rules and knowledge that in turn shape actors in adjacent domains within the innovation network, thus affecting transformations that potentially involve the entire organisation (Ciborra 1996; Garud and Karnøe 2003).

This notion of distributed agency suggests four main implications about distributed agency in digital innovation: 1) that actions leading to digital transformation takes place in multiple, distributed domains, 2) that individual actors act upon the artefact, knowledge and control structures of their local network through mindful deviation in response to localised needs and sub-optimalities and 4) that the results of such distributed actions combine to create emerging transformations of said technology, knowledge and control dimensions at the organisational level.

Agency affecting the artefact dimension involves the digital instantiation of a particular system design, which performs a set of functions for users. For instance, it can be a mobile digital infrastructure that helps firms to provide timely as well as just-in-place service to customers. Often this happens in conflict with legacy systems and IT infrastructures within the firm, which must be mitigated for the transformation of digital technology to be successful.

Agency directed at changing the knowledge dimension involves transforming the mental schema by which actors make sense of technology (Garud and Rappa 1994; Orlikowski and Gash 1994). In the context of distributed digital innovation, such change to mental schema may be isolated to a specific localised network cluster. For example, distributed changes to the cognitive schema of a specific employee group in a particular geographical location might differ from the incumbent narrative shared across the firm, thus in a small way contributing to the firm's general cognitive conventions. These general conventions and narratives emerge from a multitude of such localised contexts within the innovation network (Pentland and Feldman 2007).

Agency affecting organisational control structures simultaneously reenergises and endangers established actor relations. It has the potential to reenergise actor relationships by inspiring new collaboration, creativity, and redefining existing control structures by introducing new actors (e.g. new technologies, management systems, or individual employees or managers). On the other hand, it endangers actor relationships as digital technology may lead to reallocation of power and resources between actors in the context of the localised innovation network. For instance, competition surrounding allocation and reallocation of resources or displacement of actors who fail to conform to localised changes to control structures (e.g., legacy IT systems or, staff made redundant when failing to conform with new modus operandi).

Each of the three dimensions of distributed digital innovation relating to artefact, knowledge and control, offers different accounts of digital innovation as a distributed process. Understanding the distributed nature of micro-level actions that lead to organisational transformation therefore requires a conceptualisation of the agency dynamics through which new trajectories are created. A theoretical grounding for conceptualising the agency dynamics involved in distributed innovation can be found in path creation theory (Garud et al. 2010; Garud and Karnøe 2001; Henfridsson et al. 2009; Schienstock 2004).

Garud and Karnøe (2003) explain through an empirical study of the development of wind turbines in Denmark versus the US how distributed actors mobilise local resources to create a new emergent path for an entire industry. The result of small-scale actions involving mindful deviation from existing structures is a transformation of objects and relevance structures over time, where changes to technological infrastructure are accompanied by transformations of knowledge and organisational structures and practices (Garud and Karnøe 2001).

Following from this, distributed micro-level agency is seen as a continuous negotiation between past and future where the visions of the future are shaped by the past, resulting in continuous transformation in the present (Garud et al. 2011).

The next section addresses the issue of exactly how such localised micro-level dynamics of distributed agency are enacted through small scale interactions.

2.3.2 Micro-Level Actions

Previous sections have established how distributed digital innovation occurs as a consequence of the introduction of a novel proposition (Carlile and Lakhani 2011; Vaast and Walsham 2011) that clashes with existing actor relations to affect transformations of digital technology, knowledge resources and organisational control structures. Following from this definition, micro-level interactions can be said to contain four specific elements; proposition, opposition, controversy and outcome. Ordering these elements into a four-step interaction sequence based on their logical progression results in the following process:

1) Instantiation of micro-level network change through the introduction of novelty, typically in the form of the proposition of a new technology, knowledge resource or control structure by heterogeneous actors, 2) opposition in the form of resistance from at least two other actors in the micro-level network, 3) a resulting negotiation (Leonardi and Barley 2008), tussle (Tilson et al. 2010) or controversy (Venturini 2009, 2012) through which a new outcome is negotiated based on the specific needs and agendas of localised actors and finally 4) manifestation of an outcome that affects the course of action of one or more external actants by transforming technology, knowledge resources or control structures, whereby it contributes to shaping an organisational transformation in a more or less sustained way.

Figure 1 illustrates the sequence of micro-level actions. This sequence contains four actions that may have varying temporal overlaps and time spans depending on the micro-level actor network.

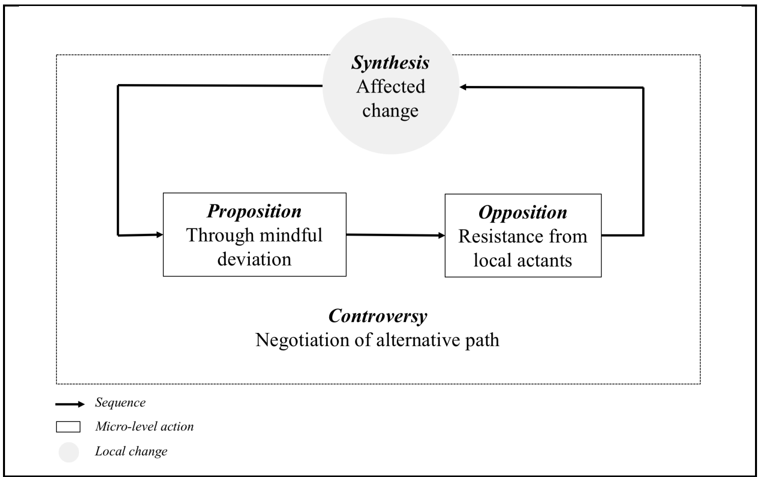

Figure 1. The dynamics of micro-level actions

Propositions can take several forms, but are generally a product of mindful deviation as covered previously in the literature review. Actors initiate the creation of a new path through mindfully deviating from known procedures, habits, or rules thus proposing a new, alternative path.

If the new proposition represents a sufficiently radical deviation from the existing path, it will endanger establishes actor relations, thereby sparking opposition from other actors. This opposition has the potential to turn into a transformational controversy if it involves resistance of at least one other actor engaging in the negotiation of an alternative outcome. Controversy therefore involves the transformation of the original proposition into a synthesised outcome shaped by the collective needs and agendas of multiple actors within the innovation network context.

As shown in figure 1, localised outcomes in turn feed into the same or connected micro-level networks as propositions, thus challenging existing actor relations. This way, local outcomes can translate and permeate across distributed micro-level networks, where they potentially lead to a series of cascading transformations. This way local outcomes affecting digital technology, knowledge resources and control structures can travel across the organisation and potentially aggregate into changes at the organisational level.

This property of distributed agency dynamics means that the way in which actors are connected in micro-level networks is of fundamental importance to understanding distributed digital innovation. The following section explores how micro-level interactions connect to form innovation networks before elucidating the analytical levels and constituent parts of such networks.

2.4 Digital Innovation Networks

Distributed innovation in networks of heterogeneous actors has long been a topic in information systems research, especially in research based on actor network theory (Latour 1996, 2004; Yoo et al. 2008; Yoo et al. 2010). The metaphor of networks that originated in the natural sciences is perturbing the social sciences where it is increasingly gaining acceptance as a model for describing complex organisational and socio-technical systems (Latour 2011; Morgan et al. 1997).

The viability of such network mapping is an area of debate in the social sciences (Carlson and Gorman 1992; Joseph 2010) as the network metaphor originates in physics and was originally applied in the natural sciences (Scott 1988). As it permeates into the social sciences, it is applied primarily as a means of accounting for increasingly complex systems of people, technology and ideas

(Tichy et al. 1979). Here, what was once a way of measuring relations between relatively static physical entities now illustrate social and sociotechnical networks of heterogeneous and ever changing agents that include any entity that acts, be it a person, technology or idea (Latour 2004). Translating networks of such loosely delimited and morphing entities into the context of distributed digital innovation requires more rigid definitions of the constituent parts of innovation networks.

Where the previous section explored conceptualisations of technological trajectories and how they shift through liminal periods of transformation, this section explores the ways in which such transformational events are distributed in innovation networks. First, innovation networks are conceptualised as networks of interconnected micro-level actions before I move on to illustrate how each of the concepts associated with innovation networks are mutually related.

2.4.1 Networks of Actions

The notion of innovation networks presented in this thesis builds on actor network theory (ANT) because it provides a powerful vantage point from which to study sociotechnical action (Callon 1986; Latour 1991b, 1993, 1996). ANT lends at least two fundamental assumptions on which to conceptualise the characteristics of innovation networks related to their most basic components; actants and actions.

First, ANT defines actants as a category that includes both human and nonhuman members (Latour 1991, Law 1992). Regardless of the varying views on the agency of technological entities in existing research, the empirical fact that digital artefacts are initiated by and affect human actors makes it necessary to include both categories.

To this end, this research conceptualises the agency of digital artefacts to extend the previous notion of nonhumans as the ‘missing masses’ of social science (Latour 1992b). In ANT, nonhuman actors have previously been conceptualised in various ways as preconditions for human society, as mediators between human agents, and even as members of political and moral associations (Sayes 2014). Definitions from actor network theory propose that in order to exhibit agency, any human or nonhuman actor needs simply to affect an observable change in the course of some other agent’s course of action (Latour 2005) with no absolute or final division made between the capacity of humans and nonhumans to exercise agency (Callon and Latour 1992). More recent theoretical developments view the agentic characteristics of technological actors as emergent properties of specific gatherings of multiple actors under certain conditions (Latour 2002, 2011). Consequently, digital transformations emerge as a property of certain configurations of innovation networks consisting of people, technology, knowledge resources, organisational structures etc.

Secondly, recent developments in ANT view sociotechnical action as a process of *“…unfolding innovation networks that emerge around issues and events”* (Garud et al. 2010). This prevalence of action over actor has been further developed into the notion of ‘action nets’ (Czarniawska 2004; Czarniawska and Joerges 1995) based on the sociology of translation (Callon 1986; Callon et al. 1983; Law 1992). The central idea behind action nets is that a structured sequence of actions within specific purposeful context determines the cast of actors being mobilised. For example, in the context of a lecture hall, students and teachers may assume the role of ‘speaker’ and ‘audience’ interchangeably based on the order of actions to be conducted e.g. lecture, group presentations, exam etc. Similarly, innovation networks are made up of multiple sequences of interrelated actions, each mobilising a different cast of actors.

The conceptualisation resulting from these two basic tenants of ANT therefore see innovation networks in two dimensions; paradigmatic transformation through actions performed over time, and syntagmatic mobilisation of actants to enact specific transformations. This classification of paradigmatic and syntagmatic levels of innovation networks builds on a distinction first introduced by Bruno Latour as a way of mapping sociotechnical change (Latour 1991a; Latour et al. 1992). Adding the level of organisational transformation established previously in this chapter, the following paragraphs will conceptualise action nets as a three-tier innovation network.

2.4.2 Conceptualising Innovation Networks

Having identified the preconditions for and actions involved in innovation networks, we can now summarise and connect the constituent parts involved in distributed innovation. Following from the notion of action networks presented in the previous section, each innovation network will consist of a) a general trajectory of organisational transformations (i.e. paradigmatic context) delaminating the scope of possible actions, b) a set of micro-level actions being performed and c) a cast of actors including humans and nonhumans in the form of e.g. physical or digital artefacts.

Table 6 consists of a set of definitions of each element of innovation networks, each representing one of the three conceptual levels; actors, actions and transformations. These empirical entities are all pertinent to processes of distributed digital innovation and should therefore all be accessible to empirical analysis.

This means that this analysis of innovation networks will account for the sequence of transformations resulting from distributed digital innovation, as well as the characteristics and interconnections of the micro-level actions that shape them. In addition, the aim is to present an unbiased inventory and account of all actors involved in the innovation network. These three elements represent different conceptual levels in the emergence of organisational transformations through distributed digital innovation, and entail different, yet interconnected, empirical entities at each analytical scope.

Table 6. Constituent Parts of Innovation Networks	
Conceptual level	**Analytical scope**
Organisational transformations	Paradigmatic sequence of organisational transformations through aggregation of path creating actions
Micro-level actions	Path creating actions performed by actor networks including proposition, opposition and controversy generating localised innovation outcomes
Distributed actors	Interrelated actant positions, or roles, in distributed innovation networks performed by heterogeneous actors including distributed human actors and digital artefacts

In order to represent the dimensionality of an innovation network, each empirical entity and conceptual level must be included in a network diagram. Innovation networks can be conceptualised as a longitudinal, k-partite network consisting of relations between actants, actions and aggregated organisational transformations defined by the set actions taking place at any given time. Figure 2 shows a selection of different ways in which innovation networks can be represented using the concepts presented above as its constituent parts.

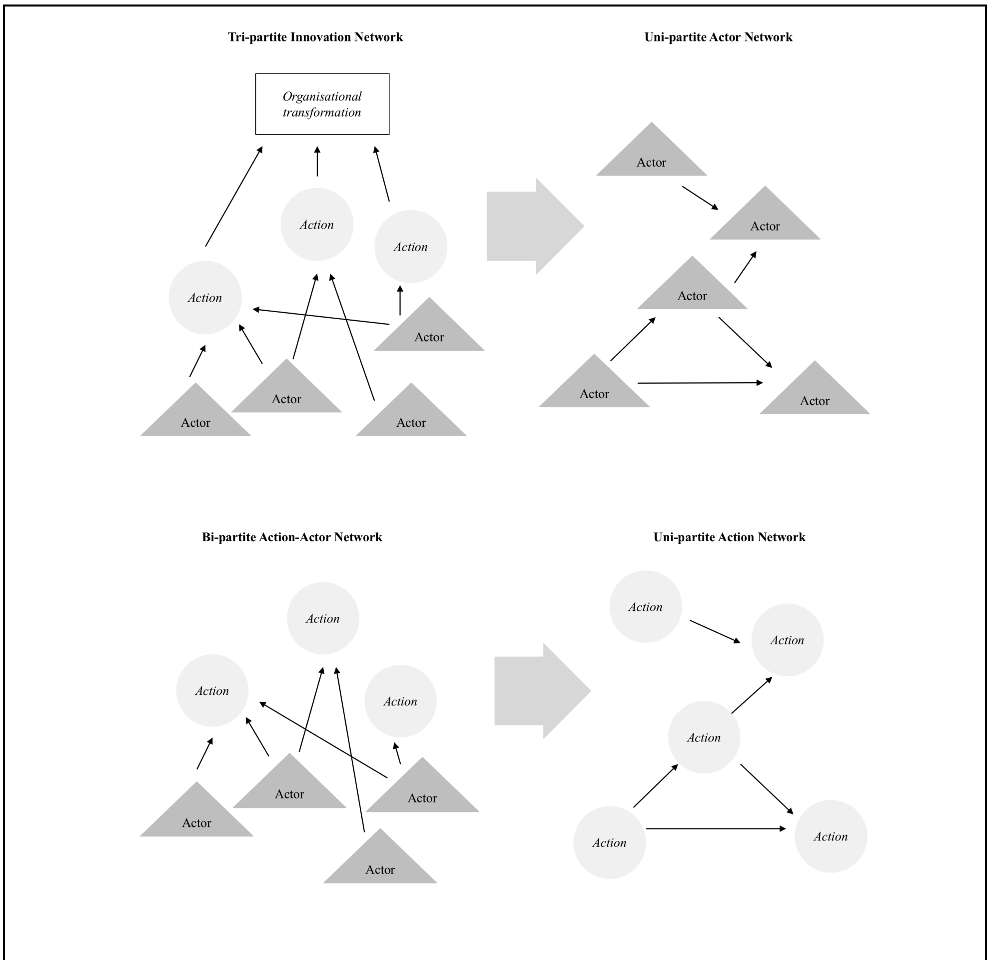

Figure 2. Representations of innovation networks

As shown in figure 2, the innovation network perspective as presented here allows for analysis of distributed digital innovation from several perspectives. Representing innovation networks as multi-partite networks makes it possible to focus on multiple aspects of distributed digital innovation including 1) the aggregation of organisational transformations, 2) the structure of innovation networks across specific distributed micro-level contexts, 3) the role of different actor types in performing specific actions, and 4) the configuration of digital actions involved in each organisational transformation.

As existing research conceptualising key aspects of distributed digital innovation has been reviewed in the course of this chapter, I now conclude by summarising the literature review.

2.5 Summary of Literature Review

It is well known that when actors actively shift an incumbent trajectory by adapting their micro-level network (cf. Garud and Karnøe 2001), this may complement or counter-act the actions taken by actors of another micro-level network, thus producing 'wakes of innovation' (Boland et al. 2007). Apart from emerging work on sequence analysis in the area of design routines (Gaskin et al. 2014) and distributed knowledge (Tuertscher et al. 2014), the existing digital innovation literature is still to explore how and under which conditions the agency of distributed actors lead to radical organisational change in the context of digital innovation.

The process by which distributed actors create trajectories of digitally enabled organisational transformation is driven by localised micro-level actions. These distributed actions have the potential to affect technology, knowledge and control dimensions, but may also occur without resulting in change to the general organisational trajectory. In this respect, distributed digital innovation can be understood as a liminal process (Henfridsson and Yoo 2013) in the sense that each micro-level change is instantiated by a proposed adaptation of a specific micro-level network to a new paradigmatic state involving controversy and 're-entry' in the form of locally bound outcomes. A trajectory shift involving multiple such controversies is therefore contingent upon the innovation paths of micro-level networks at the time of instantiation. Hence trajectory shifts are liminal moments at which the transformational powers of multiple localised micro-level controversies affecting the artefact, knowledge and control dimensions successfully combine to affect changes in a digital innovation trajectory.

Table 7 outlines how the literature conceptualises each of the three dimensions of distributed digital innovation at the organisational trajectory and micro-level agency levels respectively. It shows how the literature on technological trajectories, path dependence and path creation together provides a foundational understanding of organisational transformation in distributed digital innovation.

Table 7. Levels and Dimensions of Distributed Digital Innovation

Dimension of distributed digital innovation	Organisation-level transformation	Micro-level action
Distribution of digital technology and access to innovation	Dependence of historical path limits actors' access to innovation and manipulation of artefact architecture	Artefacts are actor networks in their own right and therefore distributed. Access to reconfiguration of material actor networks is enhanced through the layered modular architecture of digital artefacts
Distribution of competences and knowledge resources	Actors possess limited cognitive abilities and ideas are introduced at the aggregated trajectory level	As the range of skills and competencies needed for micro-level adaptations of the innovation network, translation of knowledge happens through interactions between heterogeneous actors with different and diverging agendas
Distribution of organisational control structures	Agents are constrained by their historical and systemic mechanisms (such as the market, industry standards etc.) that select the best innovations Control is embodied in the innovation system in the form of external mechanisms working at the scale of a large population of constrained agents	Organisational structures are continuously shaped through controversies between heterogeneous actors adapting to their localised context Control is understood as semiotic control of translating and articulating the contexts of other actors

Despite the strong conceptualisations of distributed digital innovation in all three dimensions and at both levels, the specific preconditions, dynamics and constituent parts of the agency involved in the agency dynamics of how small-scale actions combine into organisational transformations has not yet been researched in the context of distributed digital innovation. Furthermore, existing literature in all three dimensions of distributed digital innovation offer little in the way of explaining the mechanisms by which distributed changes converge to form radical transformations at the organisational level.

Also, while the literature has established that micro-level actions are important for organisational transformations to happen, the preconditions and characteristics of this dynamic is still scarcely understood. The reasons why some micro-level actions generate change in the general trajectory and others fail are still largely unexplored. In order to answer the research question and address this gap in the existing literature on distributed digital innovation, the following chapter outlines a methodological approach to empirically studying the phenomenon as conceptualised in this literature review.

3. METHODOLOGICAL APPROACH

Analysing innovation networks in distributed digital innovation presents a series of methodological challenges. Analysing any digitally distributed phenomenon involves simultaneously observing multiple distributed locations connected through complex infrastructures. This in itself presents a difficult task to researchers, and when adding the need for longitudinal observations of the evolving nature of digital innovations, it is clear that the research techniques traditionally used in analogue research settings are increasingly inadequate for analysing contemporary digital networks (Czarniawska 2004).

First, any study of processes of distributed digital innovation must account for the unique material and organisational characteristics of the phenomenon. This in itself presents significant challenges as processes of distributed digital innovation represent a radically different research environment to more traditional qualitative studies. Secondly, the methods used to analyse such distributed phenomena must be adapted to capturing actions and agencies over a widely distributed network across organisational and geographical boundaries. This calls for the application of digital methods, which must be adapted for qualitative case study research. Finally, the research setting must be both well delimited to provide a scope for the analysis and represent enough geographically and organisationally distributed innovation context to provide sufficient empirical observations. Analysing the actions of technological and human agents requires access to digital trace records of interactions specific to the digital innovation being analysed (Hedman et al. 2013; Venturini and Latour 2010).

This chapter describes how these challenges were met. As it does not only provide a description of methods applied in the analysis but builds a methodological contribution in the form of a new approach to conducting grounded computational analysis, this chapter unfolds the methodological approach taken in this thesis in greater depth than usually seen in a methods chapter. It does this by first accounting for the philosophical assumptions on which this thesis is based, before providing a description of the underpinnings of grounded theory methodology, before finally combining it with computational analysis to provide the research framework that guides the multi-method research approach taken in the case analysis.

3.1. Philosophical Assumptions

The philosophical assumptions underlying this thesis are based on a critical realist epistemology and ontology. As formulated by Roy Bhaskar (1975, 1979) and later operationalised as a methodology in the social sciences (Archer et al. 1998; Sayer 1992) critical realism presents an alternative to the positivist and interpretivist paradigms while incorporating elements of both in new approach to developing knowledge.

The critical realist ontology provides a consolidation of existing positivist and interpretivist paradigms in IS research by being realist, i.e. acknowledging that there are structures that exist independently of human perception, while not empiricist in that it acknowledges that such structures can be outside the domain of what is observable and must be inferred by other means. A basic assumption of critical realism is thus the separation of what the real i.e. what structures and objects exists independently of observation, the actual i.e. what actions are actualised based on these structures and the empirical i.e. what part of the actualised actions are empirically observable (Bhaskar 1979, 1998).

This means that the relationship between structures and observable empirical events is not based on causal necessity. Instead, the structure of a given object of analysis represents the *tendencies* of that object to actualise specific actions. In other words, structures enable what can happen in a given social, historical and geographical context (Sayer 2000). Instead of causally producing empirical events, structures lead to specific causal powers and liabilities that represent the tendencies of certain actions to be generated and the exclusion of others. This critical realist scientific methodology is what Bhaskar referred to as ‘retroduction’ (Bhaskar 1975, 1998), and which is essentially the same as the ‘abductive’ method previously developed by Charles Sanders Peirce as an alternative to induction and deduction (Mingers et al. 2013). The retroductive method explains a phenomenon of interest by proposing a hypothetical mechanism or a set of mechanisms that if it exists will generate given observable outcome related to the phenomenon to be explained.

In the context of IS research, the critical realist scientific method mitigates the tendency of interpretivist research to provide rich yet highly contextualised accounts individual events from the point of view of specific actors (Nandhakumar and Jones 1997) that are typically concerned with the construction of technology, and empiricist accounts of generally observable structures in large-scale systems and across populations (Mingers 2001, 2004; Smith 2006). By acknowledging the value of subjective and highly contextual knowledge of social actors, it also recognises the existence of independent structures that enable and constrain actors in a given setting. This means that research based on a critical realist methodological approach aim to provide more detailed causal explanations of a given set of phenomena and events in terms of both the interpretation of social actors and the mechanisms and contextual conditions that interact to produce specific outcomes.

Critical realism thus *"...shifts the focus to explicitly describing causality by detailing the means or processes by which events are generated by **structures, actions**, and **contextual conditions** involved in a particular setting"* (Wynn and Williams 2012, p. 789). This research ontology as first formulated by Andrew Sayer (1992) involves four elements. First, an object of analysis with a specific structure that is independent of the observed empirical events. This means that the structures of the object exist independently of how they are perceived by specific actors. Second, these structures necessarily have a set of causal powers and liabilities. What this entails is that, due to the existence of independent structures, some actions are more likely than others. These tendencies of the system to generate certain events by actualising causal powers and liabilities is often referred to as 'generative mechanism' in IS research (Bygstad 2010; Henfridsson and Bygstad 2013; Smith 2006). Generative mechanisms can be characterised as *"…one of the processes in a concrete system that makes it what it is -for example, metabolism in cells, interneuronal connections in brains, work in factories and offices, research in laboratories, and litigation in courts of law"* (Bunge 2004, p. 182). However, as mentioned above, generative mechanisms do not *necessarily* produce empirically observable outcomes. Instead, the actualisation of observable events is *contingent* upon the specific contextual conditions that are present within the system at a given point in time (Mingers et al. 2013).

Third and fourth, the contextual conditions at a certain point in time will determine what the nature of the outcome might be. Some research conceptualises this contextual contingency as a binary state of causal mechanisms either being realised or not (Henfridsson and Bygstad 2013), but this does not necessarily resonate with seminal work on critical realist methodology, which describes the contextual conditions as a shaping and mediating force in the generation of specific events (Sayer 1992). Also, in their Context-Mechanism-Outcome (CMO) framework for realist evaluation, Pawson and Tilley (1997) point out that studying the totality of a system's contextual conditions, generative mechanisms, and observable events, is necessary to establish an account of the dynamics. Because the objective of this research is to account for a process of radical transformation rather than explain the occurrence of a given set of events, I will adopt the latter more dynamic understanding of the relation between structure, causal powers of certain agency dynamics, and contextual conditions in producing a specific set of observable events. Figure 3 illustrates the relations between the four elements of the critical realist ontology that serves as a methodological foundation for this research.

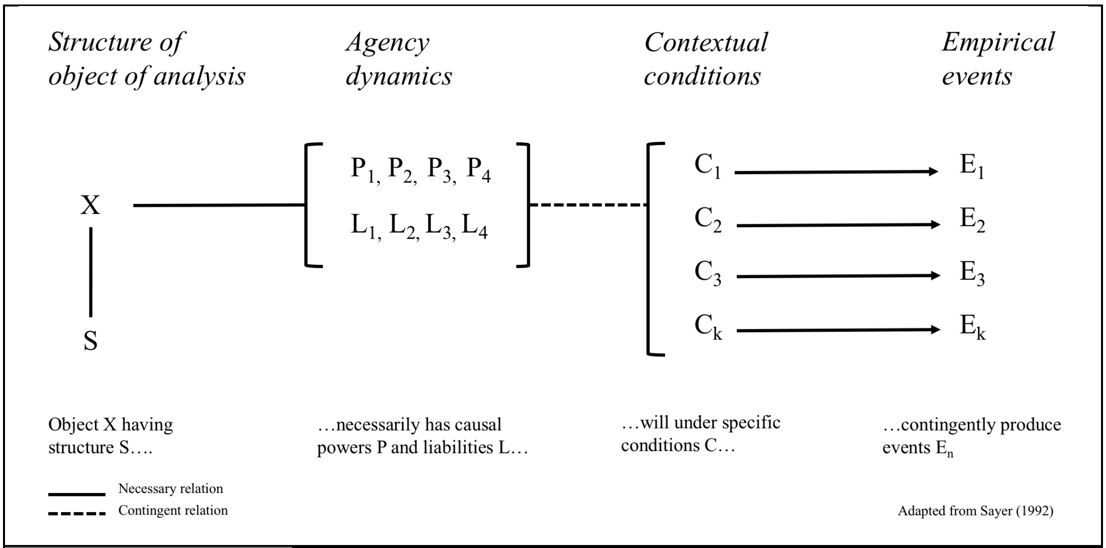

Figure 3. Overview of critical realist ontology

As illustrated in the figure above, certain relations are causal, meaning that they *necessarily* happen, while other relations are contingent. Specifically, the relation between the structure of the digitally distributed system necessarily means that it will have a tendency to actualise some actions over others. In the context of this research, that tendency due to the structure of the system can be described as 'agency dynamics'. However, these tendencies are only actualised in the presence of a given set of contextual conditions. Different contextual conditions will thereby result in qualitatively different empirical events, even when based on the same agency dynamics. Following from this, an analysis of distributed digital innovation must account for both the structure of the information system and how this changes over time, the agency dynamics that are the tendencies of the distributed user base of the system and the contextual conditions mediate agency dynamics at a given time to produce observed events.

Having established this basic ontological footing, the methodological question of how to study such phenomena in the context of distributed digital innovation presents itself. As the ontology consists of both technological and social elements that are in nature distributed and interacting via digital technology, it is necessary to apply a computational approach to developing a research design. Before explicating in more detail the computational research approach, the following section briefly addresses how the philosophical assumptions of a critical realist methodology relates to the emerging field of computational social science.

3.1.1 Critical Realism and Computational Social Science

As the phenomenon under study in this thesis revolves around a digitally distributed information system, I will now discuss how the philosophical assumptions detailed above relate to the emerging field of computational social science.

Computational social science has traditionally been occupied by scholars from an empiricist-positivist tradition applying methods and techniques from fields such as physics (e.g. Conte et al. 2012) and complexity science (Epstein 1999, 2006). However, computational techniques have increasingly been adopted in, and adapted to, humanities (Jockers 2013; Rogers 2013) and the social sciences, specifically to the study of digital traces produced in the context of information systems (Hedman et al. 2013; Howison et al. 2011), by combining qualitative and quantitative techniques (Venturini and Latour 2010; Whelan et al. 2016).

While not explicitly stated, this quali-quantitative branch of computational social science (e.g. Venturini and Latour 2010) is conspicuously congruent with recent developments of mixed-methods frameworks based on critical realism (Zachariadis et al. 2013).

As a realist philosophy, critical realism adopts the idea of a reality, which independently of our knowledge or perception of it (Archer et al. 1998; Bhaskar 1975, 1979, 1998). This is what is referred to as the 'intransitive domain' represented in this thesis through independent structures, the causal powers of agency dynamics, contextual conditions and empirical events. However, the generation of knowledge about intransitive domain is seen as a human activity that relies on the specific circumstances and processes of its production. This is referred to as the 'transitive domain' and represents our conceptualisation of reality through theories, established facts and analytical techniques and methods applied by researchers at a given time and place. Within the critical realist epistemology, knowledge is therefore created in two dimensions: *"…it is a socially produced knowledge of a natural ([hu]man-independent) thing"* (Archer et al. 1998, p. 65).

This means that the combination of rich qualitative enquiry with high resolution and rich detail and quantification of patterns at magnitude is a central tenant of a critical realist methodology (Zachariadis et al. 2012). With this notion in mind, this research therefore does not represent a 'colonisation' of the social sciences by quantitative methodology imported more or less directly from the natural sciences, but builds on emerging applications of computational methods in humanities and social science. The notion of computational social science adopted in this thesis is thus based on a critical realist epistemology and aims to establish relevant patterns of an intransitive reality by means of transitive production of knowledge through quali-quantitative methodology.

3.2 Grounded Computational Analysis

As phenomena associated with information systems in general and digital innovation in particular are increasingly distributed across geographical, organisational and temporal boundaries, the methods we use to study them are in need of adaptation. To this end, the use of computational methods are well aligned with not only the research context of distributed digital innovation, but also relates to recent research commentary proposing that it is of vital importance to IS research to not exclusively observe digital artefacts from an outside perspective but to assume the perspective of the information system (Grover and Lyytinen 2015). This means treating IT artefacts as informants that can help identify constructs and their relations and thereby build theory from digital trace data.

The method by which theory is constructed in this research is based on a grounded theory approach. It has already been established that grounded theorising in digitally distributed contexts must be able to both describe and classify this novel empirical domain and to explain and make predictions that extend beyond a specific research domain (Vaast and Walsham 2011). It is the ambition of this chapter to establish a methodology for building such grounded theory using computational techniques.

Grounded theory first gained recognition after the publication of 'The Discovery of Grounded Theory' by Barney Glaser and Anselm Strauss (1967). Notably, Bernie Glaser came from a background in quantitative methodology and was trained in qualitative mathematics, a method in which mathematical expressions, such as statistical formulas, can be stated qualitatively (Glaser 1998;

Strauss and Corbin 1998). This suggests that bridging the divide between generalizable formal representations and contextualised inductive grounding was an integral part of the DNA of grounded theory from the very beginning. Since, however, grounded theory has attracted and been the object of many myths about its lack of generalizability, including that of the researcher as a ‘blank slate’ (Urquhart 2006) and that it leads to the production of low-level theory (Urquhart 2001).

The following sections serve the purpose of disproving these myths by extending and translating the early strands of the grounded theory method to the digital age, thereby presenting a practical framework for building grounded theory using computational techniques. First, a general sequence of grounded theory is established. From this vantage point, a framework for conducting grounded analyses with computational techniques is presented and illustrated with a small-scale empirical example.

3.2.1 The Process of Grounded Analysis

Building grounded theory based on empirical data is a structured process that can be thought of as involving a number of analytical steps performed in an iterative sequence with the purpose of establishing and refining concepts and their interrelations (Urquhart 2012; Urquhart et al. 2009). Each iteration aims at identifying and saturating theoretical concepts by sampling, slicing and comparing data, thus adding layers of conceptual abstraction while maintaining the empirical granularity of previous iterations. This raises the question of where to start the process of a grounded analysis. The answer derived from the Glaserian version of grounded theory is remarkably simple: start by becoming an expert on the research domain (Glaser 1978).

In preparation for collecting the first data, the researcher should immerse himself into the empirical domain to the point of building general expert knowledge of the phenomenon being studied. This process of domain immersion has been seen as starting from initial ‘hunches’ (Miles and Huberman 1984) based on lived experience or more broadly “*...sources other than data*” (Glaser and Strauss 1967, p. 6). In order to gain such experiential knowledge, the researcher must be deeply familiar with the research domain. Glaser suggests that this initial expert knowledge will guide selection of a ‘core category′ of interest within the specific empirical research domain, also referred to as the substantive area (Glaser 1978, 1992). This core category will guide collection of the first slices of data (Urquhart et al. 2009).

The initial analytical iteration describes the empirical research domain by establishing narrow concepts and their properties. The first step is to select the area of inquiry guided by expert domain knowledge in the form of a general question or unexplored area within the empirical domain. The first slices of data are then collected within the area of inquiry. These first slices of data are rarely structured a priori, but are broken down into conceptual units with distinct sets of properties through open coding (Glaser 1992; Urquhart 2012). The result is an inventory of narrow concepts describing the area of inquiry.

The second iteration involves interpreting the initial narrow concepts to build substantive theory. Data is sampled using theoretical sampling which represents a key element of grounded theory (Glaser and Strauss 1967). Theoretical sampling involves the successive sampling of data slices based on emergent theory (Glaser

1992). To start with, data sampling is based on specific empirical assumptions about the core category, and as more slices or layers of data are sampled, the core category is gradually refined. The process stops when adding more layers of data stops affecting the definition of the core category. This is referred to as 'theoretical saturation' (Glaser and Strauss 1967) and helps determine whether a theory works i.e. whether or not it says something about what is actually going on within the area of inquiry (Urquhart 2012). The resulting substantive theory consists of a set of empirically saturated concepts related to the specific empirical domain in which it is generated (Glaser 1978, 1992). Such saturated concepts are generally referred to as a substantive theory because it explains a set of concepts within the specific empirical substantive area (Urquhart 2001). Presenting substantive theory as the conclusion of grounded research is where some of the criticism of grounded theory for producing low-level theory that is purely descriptive and does not generalise beyond the specific empirical domain in which it was created may arise from (Urquhart 2006).

Therefore, the final iteration aims at building more formal theory by 'scaling up' the substantive theory to be generalizable over a class of empirical contexts and to be relatable to other theories (Urquhart et al. 2009). Such abstraction is achieved through what Glaser refers to as theoretical coding, which means grouping high-level substantive categories into one or two core categories (Glaser 1978, 1992). This increases the density of relations between substantive concepts and adds a layer of abstraction representing a formal, generalizable theory. With every step towards a formal theory, context is necessarily stripped away from the categories for the sake of transferability and generalizability (Glaser 1978).

Figure 4 outlines this process of iteratively building grounded theory from empirical data. Even though for simplicity each iteration is depicted as a singular sequence, in practice each horizontal sequence will be repeated a number of times until satisfactory conceptualisation is achieved. Also, as shown in figure 3, the sequence of grounded data analysis repeats itself in each iteration following a structured set of steps including data sampling, data slicing, data comparison and conceptualisation. Data sampling involves mining or collecting a data set based on the criteria developed in the previous iteration. From there the data sample is divided into slices, or layers, depending on the level of abstraction and coded using open, selective or theoretical coding techniques (Glaser 1992). Finally coding is compared between data samples or populations within the sample to reveal conceptual patterns (i.e. concepts and their relations).

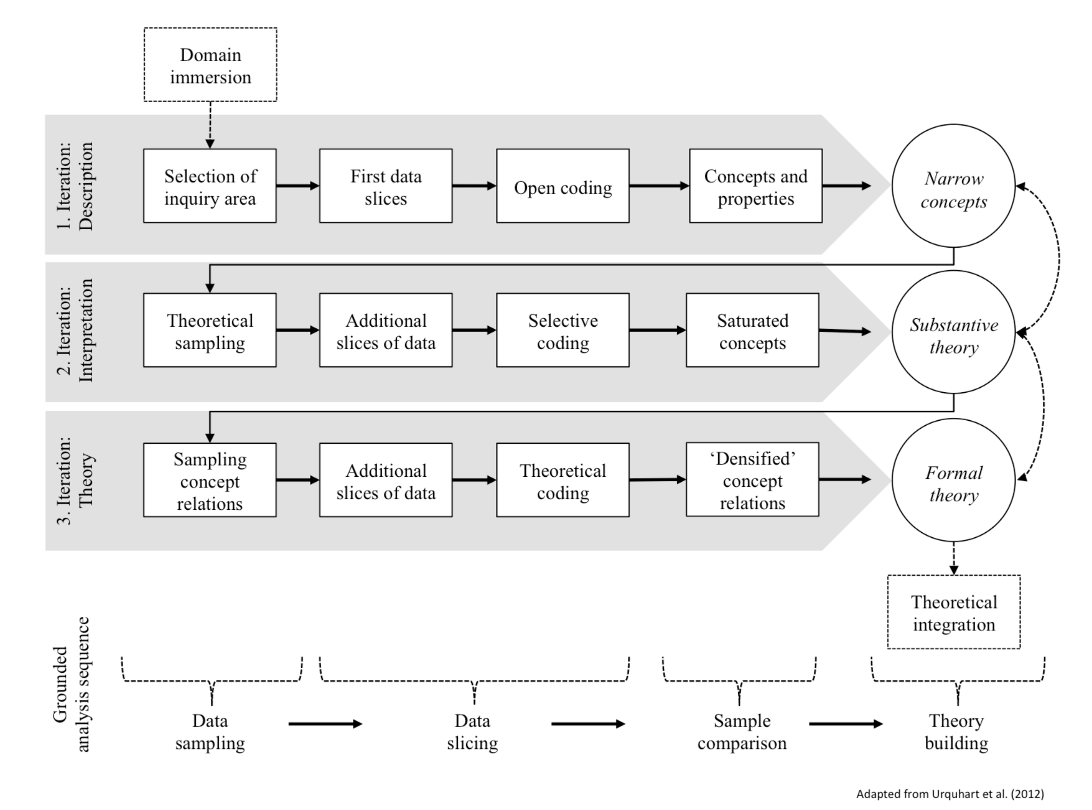

Figure 4. Iterations of grounded analysis

When data analysis has been conducted, it is of great importance to relate the resulting grounded theory to related theories to ensure that the grounded theory contributes in a valuable way to existing theoretical developments (Urquhart 2012). This is referred to as theoretical integration and means that the emerging theory should be related to existing high-level theories in the field such as structuration theory (Giddens 1984; Jones and Karsten 2008) or actor network theory (Law 1992; Sayes 2014). This final step ensures that a direct chain of evidence from each individual slice of data to general high-level theory is established.

3.2.2 Building Grounded Theory with Computational Analysis

In order to build such grounded theory using computational tools and techniques, the grounded theory process must be related to existing requirements for digital trace analysis in the social sciences in general (Rogers 2013) and to recent research on mapping digital innovations specifically (Venturini 2012). This section draws the contours of a methodological approach to digital trace data analysis based on the grounded theory process and the materiality of digital traces and environments to propose a research framework for empirical digital trace analysis of digital innovations.

Computational data analysis has for some time been applied in statistics and is increasingly integral to other disciplines in the natural sciences, especially in emerging disciplines such as e.g. genetics and bioinformatics (Jombart 2008; Kumar et al. 2001). The process of conducting computational data analysis can be described in five steps: First, the raw observed digital trace data is mined from the research domain in such a way that it provides a meaningful gradient to be observed. Second, data samples are divided into categories or fractions that fit the analysis. Then, based on the initial categorisation, the entire data set is profiled in terms of its discrete elements. This profile is then validated in a way that provides a clear categorisation across the data. These two steps have the purpose of providing a tidy data set that can be visualised and interpreted through visualisation and by adding additional variables to each sample (Schutt and O'Neil 2013).

Figure 5 reproduces a simplified schematic of the process of a data analysis associated with the so-called 'non-aqueous fractionation' (NAF) procedure in molecular biology (Klie 2011). The diagram shows how the raw data sample, in this case organic material, is transformed through a number of steps adding layers of abstraction and gradually dislodging information from the empirical matter.

First, the sample is treated in a way that reveals a particular property of the organic material called the ‘NAF gradient’. This NAF gradient then becomes the data unit being analysed. Then, the gradient material is split into discrete categories through yet another chemical process. Depending on whether or not this process reveals strong enough markers, it is repeated adding new data samples and slices until a saturated set of discrete categories can be measured. Finally, the category measurements are classified into broader groups that are in turn visualised to validate the emerging pattern.

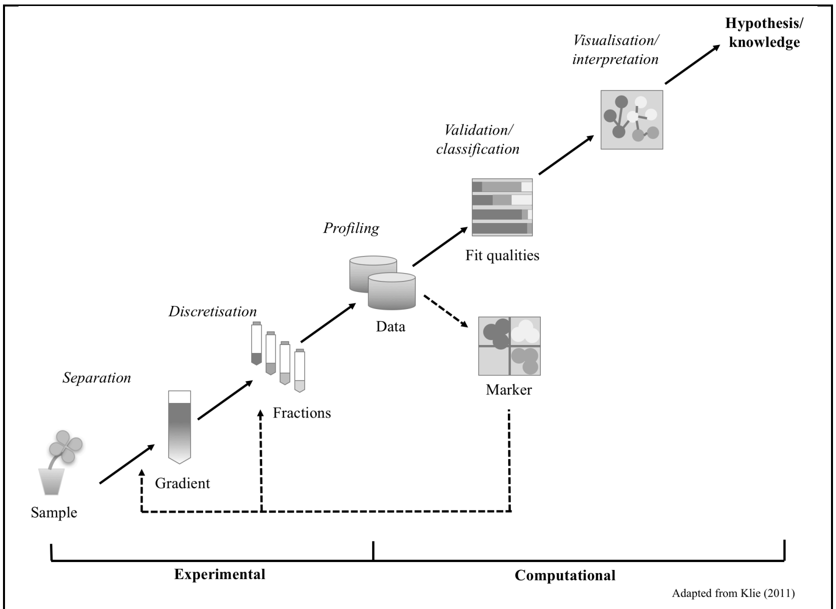

Figure 5. Data analysis sequence in molecular biology

Generalizing the data analysis sequence implied in the process described by Schutt and O’Neil (2013) and exemplified in the diagram of the NAF procedure outlined in figure 5 leads to a five-step process including; 1) data mining, 2) data unit separation, 3) data discretisation, 4) validation and classification, and finally 5) conceptualisation.

The first step involves mining digital traces. To be able to investigate as large a variety of diverse questions in as great detail as possible, a high degree of perplexity should be maintained in the raw sample of digital trace data (Venturini 2009). This means that the researcher should not simplify the number or nature of patterns to be extracted from the digital trace records. Digital trace data provides a 'found' data source in the sense that it, like organic material, does not need to be constructed with a data collection instrument such as a survey or interview protocol. Instead, trace data can be mined using programming languages such as Python or R to scrape websites or access information systems via database queries or APIs (Application Programming Interfaces). Therefore, it is important that the data mining process makes as few assumptions about the substantive domain as possible and maintains the highest possible degree of complexity and variety in the data.

The second step involves separating the data into ontological and temporal units. The raw data has such a form that it must be interpreted through a script or application to translate it into a readable format, i.e. in tabular or other structured format. As trace data samples are usually complex and multi-facetted, it is necessary to identify and define salient data units. Normally, raw digital trace data does not exist in a concise format structured for analysis and is often comprised of data from various sources. This means that data sets must be cleaned and separated into units such as e.g. posts, transactions, tweets, updates, profiles etc. In performing this separation, it is important to make sure that the number of voices that participate in the digital innovation and chronological texture is not arbitrarily short-circuited by leaving out salient data units (Venturini and Latour 2010). Therefore, the data sample should be divided into both ontological and temporal units to allow for multiple facets to be explored in subsequent analyses.

The third step refers to discretisation of data units into meaningful fractions. This includes evaluating the compatibility of emerging data units by comparing them with already included data units in such a way as to maintain them all in the same setting, thus producing a hierarchy or relative positioning of each data unit. This is especially important in tracing the processes by which one emerging ontology redefines or displaces another as is the case in digital innovation (Godoe 2000; Svahn et al. 2009). In practical terms, this means that units of trace data should in some way be turned into discrete data in order to describe the relative strength or position of each data unit.

Having mined, separated, and discretised the digital trace data we can now start identifying and validating patterns from the data. At this point it is useful to employ various data exploration and visualisation techniques to support classification of the data (Rogers 2009, 2013; Venturini and Latour 2010). This involves techniques such as traditional descriptive statistics or other descriptive visualisations such as Natural Language Processing (Chang et al. 2013; Landauer et al. 1998) and Social Network Analysis (Granovetter 1973; Prell 2012) depending on the stage of theory development. The aim is to validate the discretisation and generate pattern classifications for further analysis.

As previous research has suggested it can be difficult to draw conclusions based on descriptive visualisations such as static network analyses (Trier 2008).

Because digital traces are generated as the result of digital interactions, they are inherently dynamic, why longitudinal analysis should be conducted to empirically validate the emergence of a classification based on trace data.

Finally, once emerging patterns have been ontologically and temporally validated, the researcher should no longer question their validity as a part of the substantive domain (Latour 2004, p. 109). Instead it is necessary to conceptualise the identified patterns in order to generate and develop insights and theory from the computational analysis. This means employing theory and other data sources to develop an explanation for emerging patterns. Figure 6 shows how each computational step corresponds to the grounded analysis sequence discussed in the previous section.

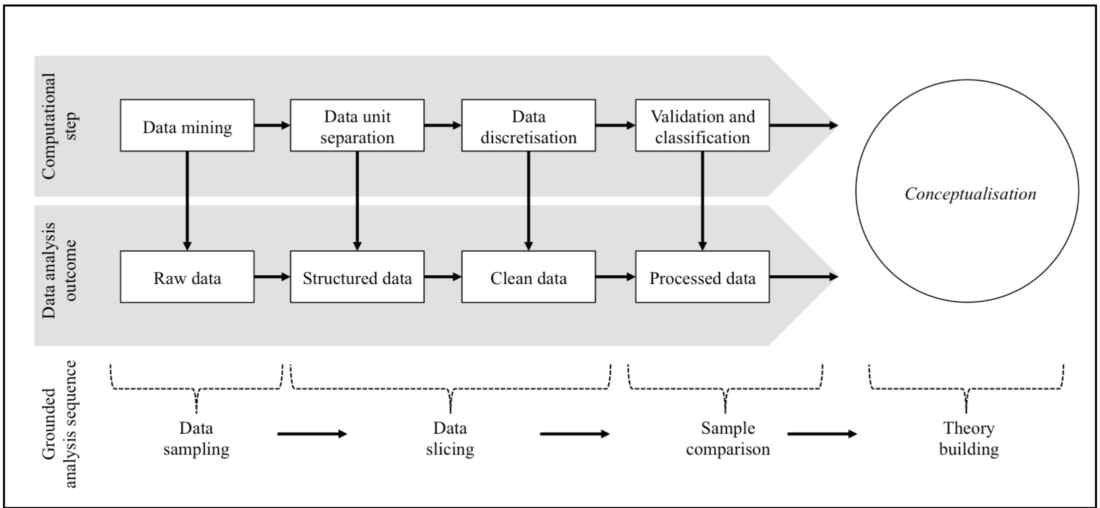

Figure 6. Grounded data analytics sequence

Looking closer at the outcome of each data analysis step shown in figure 6 reveals that digital trace data, even though thought of as observational data, undergo a series of computational processes significantly transforming the more or less structured original raw data sample into an analysis ready data set of a significantly different structure. This process of slicing and moulding the data is underestimated in at least two ways; it represents a significant analytical process which is both time consuming and tedious, and the fact that the original sample is reconstructed for computational analysis means it does not contain direct or 'objective' representations, but is prone to a series of biases including being interpreted by the researcher.

In the context of analysing processes of distributed digital innovation, the latter point is especially pertinent as the multi-facetted, distributed and temporal characteristics of the object of analysis, i.e. distributed digital innovation, means that extensive domain knowledge is a prerequisite for the researcher to make appropriate analytical decisions. This requirement bares remarkable resemblance to the domain immersion described in classic grounded theory literature (see the outline of the grounded process shown in figure 5).

Another crucial function of constant domain immersion and re-immersion in grounded computational analysis is the concept of 'iterative conceptualisation' (Urquhart et al. 2009) where theory is built in three successive iterations. After each iteration, it is necessary to relate the emerging theoretical constructs to the body of pre-acquired domain knowledge in order to make informed decisions about whether and how to repeat previous steps to increase construct clarity or proceed with the next analytical iteration. That means that analytical reflection and conditioning through domain immersion is effectively the mechanism that distinguishes grounded theory building from variance based hypothesis testing.

Figure 7 outlines a methodological framework for building grounded theory with computational data analysis techniques. The framework is formulated as a guide for applying computational techniques in each of the analytical steps, illustrated by solid arrows, for the three iterations of grounded analysis detailed in this section. It also shows examples of the reflections required by the researcher of digital innovation during domain immersion and re-immersion as illustrated by the dashed arrows.

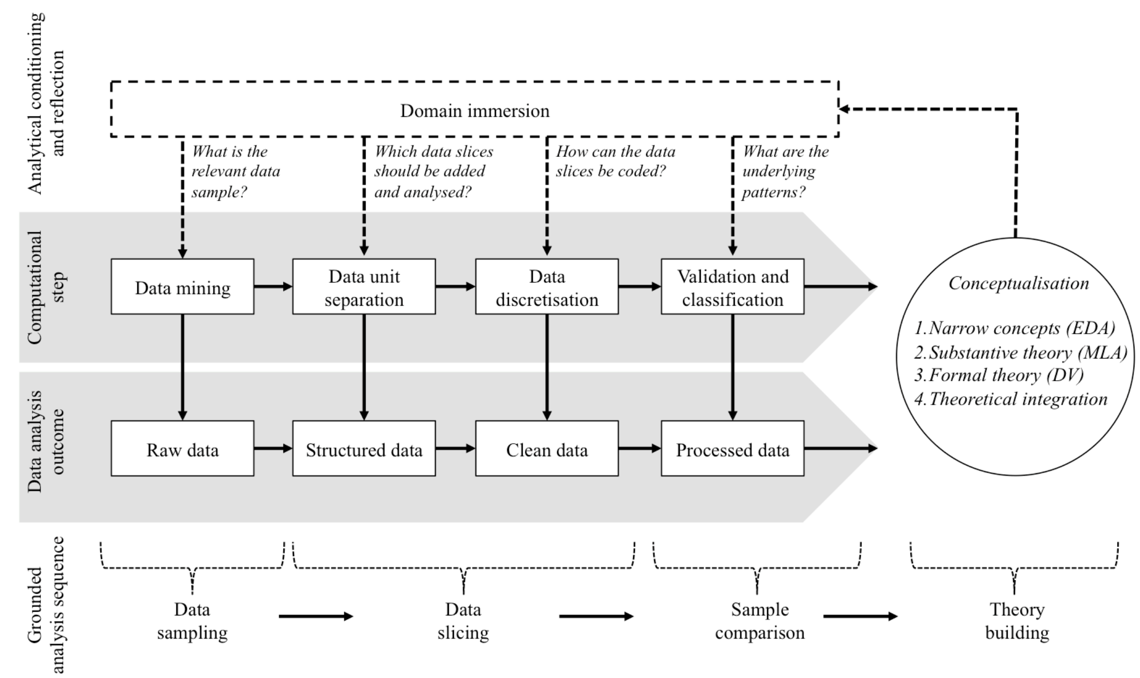

Figure 7. Building grounded theory with computational analysis

As indicated in the circular conceptualisation, the grounded computational method adopts the theory building steps of a Glaserian grounded theory method discussed in the previous section; narrow concepts, substantive theory, formal theory and theoretical integration. The way in which each step is achieved is where a computational method needs to adopt general data science techniques, specifically explorative data analysis (EDA), statistical models and machine learning algorithms (MLA) and data visualisation (DV) techniques (Schutt and O'Neil 2013). As indicated in figure 6, the first analytical iteration with the purpose of building narrow constructs can be supported through explorative data analysis involving simply describing the characteristics of the data through means of summarisation and visualisation (Tukey 1977).

Following from this, substantive theory consisting of saturated concepts can be built by fitting appropriate statistical or machine learning algorithms such as various clustering, neural network, genetic and deep learning algorithms (Bishop and Nasrabadi 2006; Goldberg and Holland 1988; Marsland 2014).

Relating and visualising the results of the formal theory building process involves data visualisation (Ware 2012). As illustrated in the figure 6, these computational techniques are just that; techniques. They cannot by any means be automatically applied and need to be treated as any other qualitative coding exercise relying on prior domain knowledge and analytical conditioning and reflection by the researcher.

The attentive reader will have noticed that the model shown in figure 6 is structured as a single iteration of the grounded theory process discussed earlier. The model should therefore be seen as contingent on the specific research design including the availability of additional, possibly non-digital, data and the patterns discovered in previous analytical iterations. The grounded computational analysis method can therefore be applied as part of a purely computational study or as a component of a mixed-methods research design (Zachariadis et al. 2012) replacing one or more analytical iterations. To exemplify the grounded computational analysis method, the following section describes a brief empirical example of a grounded computational analysis.

3.2.3 Applying Grounded Computational Analysis: An Empirical Example

The following brief example illustrates the practical implementation of grounded computational analysis in a single research iteration, specifically to build narrow concepts using explorative data analysis. To this end, a relatively small-scale trace data analysis of a Facebook-like Social Network for PR professionals in Denmark, hereafter referred to as PRnet, was conducted. As I have previously worked closely with the CEO of the company that developed and hosted PRnet and was employed in a major PR agency, I had prior to the analysis been thoroughly immersed into both the technological and social dimensions of the research domain. Discussing the triggers, that make an online social network 'take-off' in the sense that it reaches a critical mass of users, we decided to look closer into the role of specific users on network growth. The following discussion explicates each step in the grounded computational analysis method before reviewing the limitations and implications of grounded computational analysis.

Data mining

To analyse the PRnet online social network example we first retrieved a raw digital trace data sample using a SQL database queries. This saved the trace data from the online network into a comma-separated document. The raw and unstructured data represented digital traces generated through interactions on the online social network. The digital trace data covered a seven-month timespan from the formation of the PRnet community consisting of 13,101 connections created by 2,149 members.

Data unit separation

In the fairly simple PRnet example, the raw data contained traces of connections between members, member name and affiliation and timestamps for each connection. The raw data was separated into a structured data table where each row represented the formation of a connection on the network using a Python script. Already at this point made some initial decisions are made about the ontological hierarchy inherent in the data by foregrounding connections as the most salient ontological unit.

This has direct consequences for the scope of analysis that can be employed at later stages in the process, as it would be possible to choose a different ontological unit such as individual members, organisations etc. Specifically, the raw data was separated into a tabular form with each row representing a connection, and each column representing source node, target node, time stamp, and affiliation respectively. This structured format allowed for further analysis of our ontological units by separating them into distinct units.

Data discretisation

By plotting the number of members with at least one connection at each time interval (1,899 in total) the emergence of the online social network over the first six-month after launch is visualised, thereby identifying the emergence of ontological units, i.e. network members, over time.

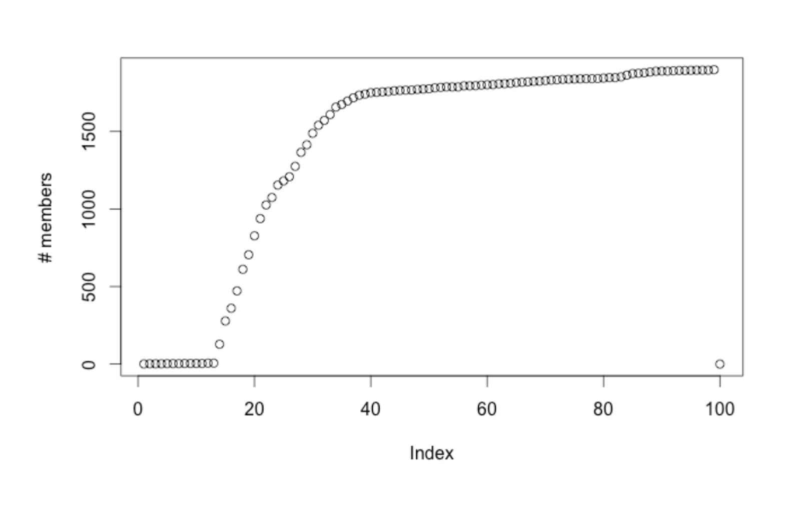

Figure 8. Connected network members over time

Figure 8 summarises the number of connected users at each indexed time interval. This confirms that indeed take-off in user adoption happens at a specific time interval indicating a “take-off” phase. In fact, by plotting average actor degree in our time series, the phase pattern indicated in figure 8 was reproduced on a continuous scale of node degree. Consulting the data reveals three phases in the emergence of PRnet: the first phase from time index 0 to 17 representing a pre-formation phase, a take-off phase between time index 18 and 40, and a consolidation phase from index 41 to index 100. This way we have and identified at least three discrete units in the digital ontology.

However, in order to analyse the shifts by which the three phases are delimited, I decided to measure the degree to which each member is connected to other members. This choice was informed by previous domain knowledge of highly connected central actors in the industry and was chosen as a coding scheme to describe this pattern in the data.

The open source social network analysis software Gephi (Bastian et al. 2009) was used to compute connection degree for each member. Degree, also referred to as connectivity, indicates the number of connections for each member. For good measure, both in-degree (number of links directed to each member), out-degree (number of links from each member) and member degree (total number of connections for each member) was computed. The average member degree for the entire network over time is plotted in figure 8.

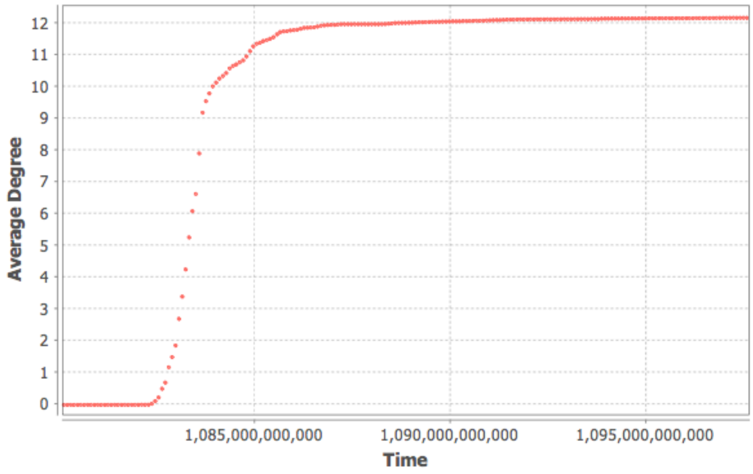

Figure 9. Average node degree over time

As the plot in figure 9 shows, average degree increases and flattens in a similar pattern to that of the member adoption plot. This indicates that new members when joining the network connect to existing members rather than form separate disconnected clusters. It confirms that connection degree is a valid metric for coding the emergence of the three phases.

Validation and classification

In order to validate the degree metric and use it to code members in the network, a graph visualisation of the network was generated using Gephi as shown in figure 10. The illustration is drawn making node size dependent on the in-degree to which each member receives connections from other members and node colour is based on outgoing connections. The colour of edges, or lines between nodes, is defined by the in-degree of the target node, i.e. the number of connections pointing to the target member.

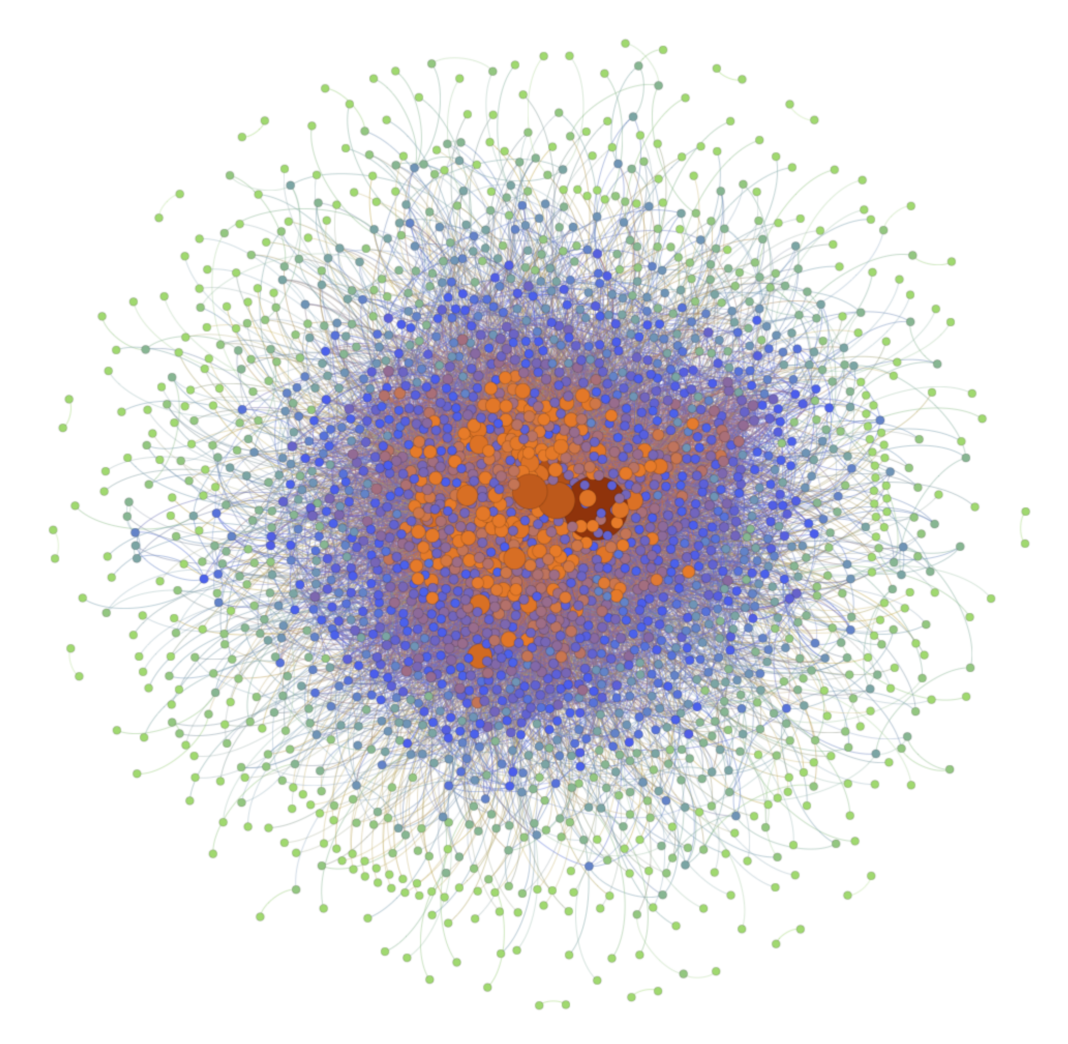

Figure 10. Diagram of PRnet validating degree classification

The graph diagram reveals an emergent pattern where members are located in one of in three spheres depending on their degree of connectivity. We can now distinguish a highly connected core (orange) with an orbiting sphere of medium connectivity (blue) and a green halo of loosely coupled members.

Having extracted this pattern from the data and validated it through visualisation, a classification of network members emerges. Where to some extent this classification relies on domain knowledge, e.g. the difference in degree is important, the resulting classes and the boundaries between them emerge exclusively from empirical analysis of the digital trace data.

In order to further validate the temporal and ontological classifications of the professional network, I generated similar network visualisations for each phase and computed the corresponding average degrees as illustrated in figure 11.

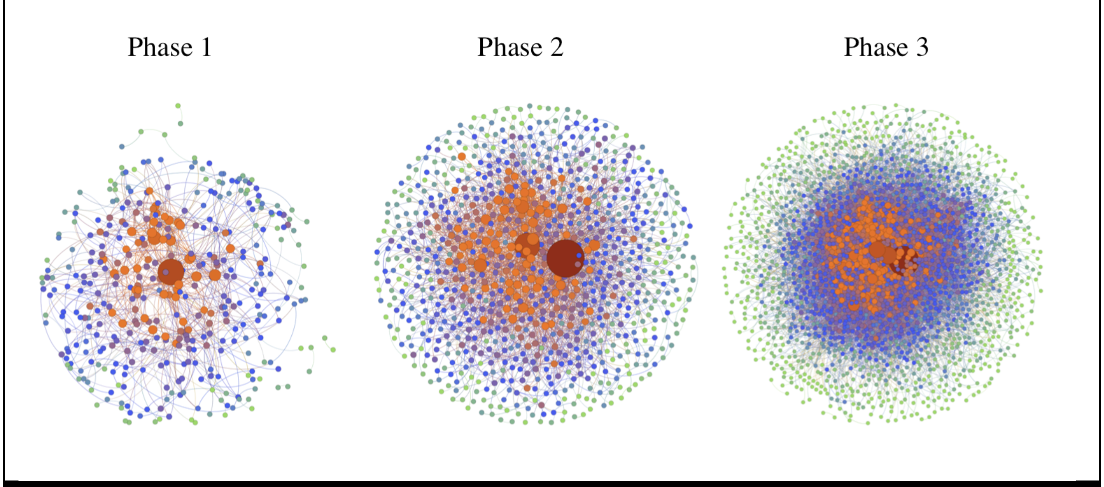

Figure 11. Emergence of PRnet in three phases

As the network visualisations in figure 11 illustrate, the cumulative position of the network's most central members is reinforced over time as the community grows from the periphery around a central group of highly connected individuals.

Interestingly, the material properties of digital trace data, i.e. the temporal separation of relational data units, afford detailed temporal validation of the otherwise static classification of ontological units revealing dynamic patterns in the data. These patterns emerging through grounded computational techniques are the basis for the construction of concepts and their relations and thus conceptualisation and ultimately theory building.

Conceptualisation

As the analytical iteration illustrated in the PRnet example leads to the construction of narrow concepts using explorative data analysis, conceptualisation consists of an inventory of narrow concepts describing the area of analysis. In the PRnet example, this inventory includes three temporal phases and three member categories defined by the connectivity of each member. This initial inventory also hints at some relations between the narrow concepts, specifically at least three patterns, or narrow conceptualisations, can be inferred from the data analysis:

1) The PRnet network emerges in three phases including pre-formation, take-off and consolidation phases
2) Members are divided into three distinct types by being part of either the dense core, connected orbit or the loosely connected halo, depending on the degree to which they are connected to other members
3) The online network emerged around a highly connected core group and took off with the inclusion of a large group of connected followers

The analysis does not specifically show whether new members transition from the periphery to the centre or are a part of a member group by virtue of their profession, seniority, community standing or other attributes. In order to answer more detailed questions such as which mechanisms drive member adoption and mobility and what type of members are more likely to appear in which tier, more data must be mined or sliced based on the empirical conceptualisation of narrow concepts and subjected to a similar analytical process.

The PRnet example deliberately includes very little text analysis as it aims to illustrate how relatively 'thin' digital traces of distributed social interactions can be coded and interpreted as a text. Closer semantic analysis could have been included in the next iteration to saturate the narrow categories derived from this explorative data analysis thus generating substantive theory.

3.3 Limitations and Implications of Grounded Computational Analysis

A recent research commentary calls for research to take the perspective of the IT artefact rather than treating technology as exogenous static entity (Grover and Lyytinen 2015). In the context of digital innovation this means unravelling the black box of IT artefacts and adopting the point of view of the digital artefact when building theory. The grounded computational analysis method is an attempt to apply computational tools and techniques in the process of grounded theory building.

Grounded computational analysis provides a method for analysing distributed digital innovation beyond variance based hypothesis testing. The combination of computational techniques and grounded theory building makes it possible to conduct research aimed specifically at understanding distributed phenomena related to digitisation and the impact of digital technology. This has the added effect of deep immersion into the digital artefact itself thus building theory from the 'inside-out' perspective of digital technology rather than the 'outside-in' perspective of traditional qualitative methods.

With regards to the practice and process of conducting such research, applying computational methods means adopting a context independent inclusion criterion for coding, in the form of computer code and scripts, that to a certain extent formalises the link between data sample and analytical coding. This happens in such a way that the coding scheme itself is, beyond the initial data mining, agnostic of the research domain and specific empirical context as long as the data format is consistent with the computational coding scripts. The introduction of computational coding scripts has at least two implications for the validity of the emerging theory: First, computational coding scripts allow for visualisation and quantification of the link between data samples and theoretical constructs, thus making the chain of evidence more transparent. Also, it potentially leads to transferability of coding schemes across empirical contexts within the scope of the theory, allowing for some measure of empirical replicability and 'theory scoping'.

However, despite these potential benefits with regards to transparency, replicability and generalizability of grounded theory, computational analysis also introduces a number of limitations by way of relying on data that are created through existing systems, platforms and infrastructures. The first limitation stems from the design of the system from which digital traces are mined, and specifically the agendas of the people designing and managing said system. Each digital innovation is built with a set of affordances with the purpose of promoting certain behaviours and deterring others, thus producing digital trace data with an inherent 'design bias'. In conducting grounded computational analysis, it is important to reflect on and explicate such design bias.

The second limitation originates in the way in which digital trace data is transmitted and recorded in digital data repositories. Being mindful of the materiality of digital traces, they are inherently connected and time stamped. This means that grounded computational analysis is restricted to identifying patterns of processes, relations and meaning. As both processes and relations are dynamic and contingent in nature, grounded computational analysis should not be applied to derive universal statements about the properties of certain constructs, but to explain in detail the contingencies and relational patterns that emerge from the research domain. A final word of caution is that applying a new set of computational techniques to grounded theory building does *not* mean automating basic analytical reflection or replacing fundamental analytical principles such as the acquisition of domain knowledge, theoretical sampling, and integration to existing theory.

This being said, grounded computational analysis proposes a method for analysing an emergent phenomenon of distributed digital transformations and unlocking the black box of the digital artefacts at their core. Consequently, a preliminary set of guidelines of grounded computational analysis can be formulated as; 1) acquire domain knowledge 2) take the perspective of the digital artefact 3) question information systems as you would documents or human respondents (this includes learning the language of information systems, namely computer code) and finally 4) use computational techniques to build rather than test theory.

Grounded computational analysis is neither variance based hypothesis testing nor, in the traditional sense, fully interpretivist. In this respect, and considering the reflections above, grounded computational analysis represents an approach to building theory of distributed digital innovation that might be labelled as 'quantifiable qualitative analysis'.

The following chapter implements the grounded computational analysis approach in a multi-method research design to study the agency dynamics of distributed digital innovation.

4. RESEARCH SETTING AND DESIGN

Building on the grounded computational analysis method, this section presents the research design applied in the Barclays case study. First, a brief reflection on the criteria for case selection are described before presenting an overview of the research design and moving on to a more detailed account of the three-step process of data collection and analysis.

4.1 Case Selection

To study agency dynamics in distributed digital innovation, I selected an organisation that pursued a new, recognisable innovation trajectory enabled by digital technology. I needed a research setting in which new technology played a distinct role as a catalyst for innovation across multiple actors. Barclays' new frontline service support system, from here on called BankApp, satisfied these characteristics and showed initial signs of having transformative potential.

Early indications from a series of meetings with stakeholders close to the project suggested that; a) while a group of individuals and specific actors drove the change project, there were multiple actor groups and micro-level networks involved in the innovation process, b) the change involved a new mobile infrastructure for front-line customer service suggesting some level of distribution, c) the change was transformative and significant across three dimensions; artefact (new approach to front line digital solutions), knowledge (change to knowledge practices and resources in the bank) and organisational (significant changes to the governance structures and physical layout of branches), d) I initially observed controversies related to the new innovation path clashing with existing practices shaped by the highly regulated banking industry, and finally e) I gained significant access to multiple sources of data.

Taken together, these reasons made Barclays an appropriate setting for studying distributed digital innovation as the resulting radical transformation of the front-line customer service unfolded. Following from the initial meetings, I engaged in a more structured process of data collection with Barclays in December 2012, immediately after the first release of the new mobile infrastructure that underpinned the transformation of frontline customer services in the bank.

4.2 Data Collection and Analysis

The following sections describe the research design applied in this thesis in a three-step process (see Table 8). The objectives of each analytical step aim at describing the chronology of organisational transformation, conceptualising the innovation network context and explicating and evaluating the agency dynamics by which organisational transformations emerge from multiple distributed actions situated in micro-level networks. Each step corresponds with and aims to address one the three research sub-questions.

As the goal was to generate a grounded process theory of agency dynamics in distributed digital innovation, the research design is based on the grounded computational approach described in the previous chapter, combining computational data collection and analytical techniques with more traditional qualitative analysis and theory building methods. As such, the research design employed in this research is structured as a multi-method case study (Mingers 2001; Venkatesh et al. 2013; Zachariadis et al. 2013), designed to capture the case chronology, contextual conditions, and mechanisms of agency dynamics in distributed digital innovation (cf. Pawson and Tilley 1997).

Creswell and Plano Clark (2011) suggest that in constructing a mixed methods study, the researcher should seek to integrate two or more sources of data so that their combined use provides a better understanding of the research problem than one source or the other in isolation. In doing so it is important to establish the prominence of each data type in data collection, analysis and results (Schifferdecker et al. 2008). Following these directions, I collected several data types including interviews, documents, field observations and digital trace data. A more thorough description of how each data source was collected can be found later in this section, as well as an outline of the specific techniques used in data analysis. A more detailed account of each analytical technique can be found in the appropriate sub-section in Chapter 6, and the analytical scripts used in the digital trace data collection and analysis can be reviewed in Appendix 2.

Following Zachariadis et al. (2012) I constructed the mixed-methods research design by combining each data source and its equivalent data collection and analysis techniques in such a way that, put together, they inform the general research question of how digitally distributed actions lead to radical organisational transformation, better than one single data source or method. This framework combining the various methods applied is shown in figure 11.

The methods and equivalent data sources employed in the case study are divided into two groups consisting of intensive/qualitative methods with relatively small samples where data collection involves a high degree of personal interaction and context submersion, and extrinsic/quantitative methods prompting the collection of large samples of trace data with no or little direct involvement, analysed using computational methods.

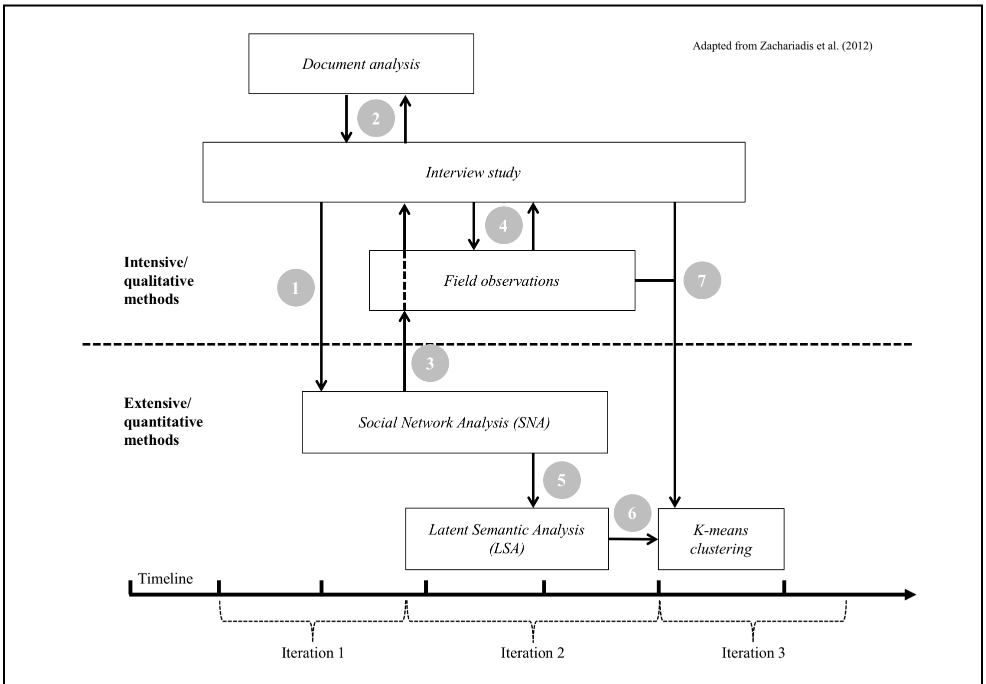

Figure 12. Mixed-methods research framework

The arrows shown in figure 12 represent interdependencies between methods where results from one method have informed the application of another method thereby creating methodological synergy that is more effective in answering the research question than each method in isolation. The specific synergies mobilised in this multi-method research framework are represented in figure 11 by numbered dots. The seven methodological synergies in the mixed-method research framework include the following:

1. Interview study identified key actors at specific points in the case history used to focus the social network analysis

2. Document analysis was used to inform interview protocols, just like initial interviews informed the understanding and analysis of collected documents
3. Results from the social network analysis guided selection of field observation sites and informed the structure of interview guides and informant selection for subsequent interviews
4. Field observations were focused on specific locations informed by initial interviews and in turn provided more detail to interview protocols
5. Results from social network analysis were used to validate the number of micro-level controversies identified using latent semantic analysis
6. Micro-level controversies identified in the latent semantic analysis provided input for k-means clustering to detect agency types
7. Results of the qualitative coding of document analysis, interview study and field observations were combined with cluster analysis to generate a typology of micro-level agency

As indicated in figure 12, data collection and analysis was conducted in three iterations with the purpose of analysing 1) the case chronology of episodes of transformation, 2) the innovation network context for each period of transformation and 3) the distributed agency dynamics by which micro-level actions combine to affect organisational transformations. Each analytical step is outlined in table 8 and detailed in the sections following below.

Table 8. Data Collection and Analysis			
Research iterations	**Data collection**	**Analytical techniques**	**Theory building objectives**
1. Describe organisational transformations	*Interview study* - 24 in-depth interviews *Document analysis* - 89 design documents (technical specifications) - 43 presentations, minutes, and strategy documents *Participant observation* - 5 on-site observations	*Qualitative coding* (e.g. Glaser 1978; 1992; Urquhart 2009; Berends and Lammers, 2011)	*Narrow concepts of structures and events* Chronology of 14 critical events in which micro-level actions accumulated to affect organisational change Identification of five episodes of organisational transformation Explication of the structure of the distributed system
2. Conceptualise Innovation network	Digital trace data covering a 15-month period from the pre-release stage in December 2012 to May 2014 2338 connections between 1038 actors interacting around the BankApp project	*Social network analysis* (e.g. Granowetter 1973; Wassermann and Faust 1994; Venturini 2012)	*Substantive theory of contextual conditions* Identification of relation between critical events through involvement by key actors Analysis of organisational and micro-level innovation network for each transformation
3. Explain distributed agency dynamics	12,746 lines of text representing 1937 specific interactions from digital trace data including announcements, feature requests, and discussions of technical and governance issues	*Computational content analysis* (e.g. Deerwester et al. 1990; Mayer et al. 2008)	*Formal theory of agency dynamics* Identification of micro-level actions Typology of five agency dynamics Explication of the agency dynamics patterns for each organisational transformation

4.2.1 Iteration 1: Describing Organisational Transformations

First, I wanted to trace a chronology of key events relating to micro-level changes in one of the three dimensions of digital innovation, and identify their relation to corresponding episodes of organisational transformation. To achieve this I employed three complimentary qualitative data sources: interviews, document analysis, and participant observation. I conducted 24 semi-structured interviews (average length: 41 minutes) with managers, developers, branch managers, and branch staff. The interviews were recorded and transcribed verbatim, generating some 173,440 words of data. In addition, I collected a number of presentations, meeting notes, and strategy documents specifying Barclays management's reflections and motivations in each episode of organisational transformation.

Most importantly, however, the document analysis involved 89 design and strategy documents outlining technical and strategic specifications for the BankApp project. By collecting multiple versions of the same documents for comparison I was able to pinpoint episodes of transformation where specific organisational changes were invoked.

In order to gain a deeper understanding of each episode of organisational change, I supplemented the interview study and document analysis with participant observation of (a) branch and frontline support managers to record how micro-level outcomes affected organisational changes, b) developers and designers to further understand the process which the project was implemented through digital technology and (c) branch staff servicing customers in branches where BankApp had been piloted to observe first-hand the effects of the new mobile technology on frontline customer service.

I initially coded the qualitative data in a research database to identify critical events in which micro-level actions the trajectory of the project using the qualitative analysis software Nvivo. Cross-coding interview and document data I then applied structured codebook analysis (MacQueen et al. 1998) to establish organisational transformation episodes for each series of critical events.

Consistent with Langley (1999) and Berends and Lammers (2010), I then visualised the case chronology by drawing diagrams of the sequence of accumulation events and organisational changes to conceptualise the process by which micro-level actions related to organisational transformation throughout the case history. In line with the definition of distributed digital innovation provided in chapter 2, I structured the diagram (see figure 12) to illustrate accumulation events in three dimensions: artefact, knowledge and control.

4.2.2 Iteration 2: Conceptualising Innovation Networks

In order establish the connection between organisational transformations and distributed micro-level actions I analysed the actor network in two ways; first I first identified relevant actors involved in each event following directions from previous literature on mapping innovations (Latour 1991a; Venturini 2009) by identifying actors by their involvement in specific events, and secondly I conducted a social network analysis based on digital trace data of multiple interactions between actors.

Initially I recoded the qualitative data mapping for each specific event in a two-dimensional matrix with events on one axis and involved actors on the other axis in accordance with previous directions for mapping socio-technical networks (Latour 1991a; Latour et al. 1992; Venturini 2012). This resulted in a deep qualitative description of the involvement of salient actors and actor groups in specific events throughout the case history allowing me to categorise each actor group in terms of propositional or oppositional involvement in each innovation outcome.

To analyse the innovation network at the individual actor level I sampled additional network data from the collected digital records of interactions imbedded in an internal information system. Howison et al. (2011) refer to this type of data source as ‘digital trace data’, that is, longitudinal data, which can be extracted from digital records of social events that are produced and stored in an information system. I extracted digital traces from an online work group concerned with the development and integration of BankApp. In total we extracted 1,937 digital records to the amount of 12,746 lines of text including team announcements, feature requests, and discussions of technical and governance issues covering a 15-month period from the late pre-release stage in December 2012 until May 2014.

This provided me with significant volumes of longitudinal, semantic, and relational data representing interactions between diverse stakeholders within Barclays allowing me to trace innovation network and identify transformation events throughout the case history. As I wanted to measure actor distribution over time, I used specific mentions from the digital trace data to extract 2,338 directed interactions between 1,038 distinct actors related to the project. The data that was extracted includes metadata such as author type and timestamps for each interaction.

Using the open source social network analysis software Gephi (Bastian et al. 2009) I then computed and visualised the innovation network throughout the 15-month period (Granovetter 1973; Wasserman and Faust 1994). Specifically, I measured network modularity (Boccaletti et al. 2007) for the event sequence corresponding with each episode of transformation and identified highly connected micro-level innovation network clusters using the standard resolution of 1.0. Because each interaction in the digital trace data was time stamped, I was able to compute the longitudinal evolution of the innovation network relating to BankApp over time and identify the distributed micro-level network clusters for each episode of organisational transformation.

In order to account for the nature of the involvement of the most salient actor groups, I then recoded the qualitative data identifying each actor group by its involvement in specific events in terms of acting in either a proposing or an opposing capacity. By cross-referencing this coding with the list of actors from the BankApp work group, I was able to verify the nature of the involvement of salient actor groups in the emergence of each organisational transformation.

4.2.3 Iteration 3: Explaining Distributed Agency Dynamics

The purpose of the final step was first to measure the occurrence of micro-shifts during the previously identified episodes; and second, to identify distinct types of micro-level agency enacted in the digital trace data. In order to measure micro-level agency in the digital trace data, I applied Latent Semantic Analysis (LSA) techniques (Deerwester et al. 1990) using the open source statistical framework R (Meyer et al. 2008).

LSA measures semantic closeness by comparing large quantities of documents by co-occurrence of specific input terms and concepts. LSA accounts for the actual language use of actors by accounting for polysemy and synonymy. Using LSA a term-document matrix was produced based on the likelihood of occurrence of terms in each digital record. Specifically, LSA calculates the likelihood of each term to occur in each record based on the assumption that closely related terms will occur in similar documents (Landauer et al. 2004). The term-document matrix produced by LSA can be used as a vector space model, i.e. as an algebraic model for representing text data as vectors of semantic concepts. (Salton et al. 1975). This vector space model was then used to interrogate the data to identify emergent concepts in a given body of text (Callon et al. 1986).

I first created a search query containing terms associated with micro-level agency, i.e. terms representing the three elements of proposal, opposition and controversy derived from the literature review. The concept vector contained terms such as “proposal”, “innovation”, “deviation”, “issue”, “transfer”, “transformation” etc. Altogether, the search query contained 89 terms related to micro-level agency. Following Deerwester et al. (1990), we then calculated cosine similarity between this search vector and the vectors representing the digital records based on the LSA scores. This way high cosine similarity can be interpreted as higher importance of concepts related to micro-shifts expressed in the digital trace data.

In order to identify distinct types of micro-level agency in the data, we first applied the k-means clustering algorithm (Landauer et al. 1998) using R. Unlike alternative methods such as e.g. Polarity Inducing Latent Semantic Analysis (Chang et al. 2013), applying cluster analysis to the latent semantic space generated from the LSA allowed us to account for semantic associations in actual language use. Following instructions by Hothorn and Everitt (2014, p. 251 ff.), I determined an optimal number of five clusters as described in the corresponding section of chapter 5.

Based on the cluster analysis I generated a typology of agency dynamics based on concepts associated to micro-level actions through language use in the online project group. This initial typology was then compared with interview and document coding to provide texture and depth to each type of agency dynamics. Because the data contained timestamp information for each record, I was able to attribute differences in agency levels over time to each micro-level agency dynamic and use spikes in agency levels to delimitate phases in the case chronology.

4.3 Summary of Methodology

The methodological approach developed in this research combines grounded theory building methods with computational analysis techniques to enable deep analysis of distributed interactions taking place in the context of a digital platform. This grounded computational analysis approach serves the dual purpose of affording access to digital records of distributed interactions at both scale and depth, and also leading to theory building from the 'inside-out' perspective of the digital artefact being studied.

The grounded computational analysis approach was implemented in a three-step, multi-method research design corresponding to the research iterations described in the methodological approach. The research design included the collection of multiple data sources including traditional qualitative data in the form of interviews, documents and observations, as well as digital trace data representing numerous interactions relating to the BankApp project. The data were collected in such a way that they their combination generated at least seven synergies that were more effective in answering the research question than each data source in isolation.

Data analysis is structured in three iterations, each with the purpose of adding layers of conceptualisation and ultimately to build a theory of agency dynamics in distributed digital innovation. The first iteration establishes key events in which micro-level actions potentially affect organisational transformation. This provides a thin conceptualisation of the case by establishing a sequence of micro-level events and transformations. The second iteration identifies the innovation network context relating to each period of organisational transformation with the purpose of characterising the actors involved and determining innovation network structure for each episode of organisational transformation. The final iteration analyses the nature of micro-level actions and that dynamics by which they combine into organisational transformations.

The next chapter applies the methodological approach and research design to a case study of the radical transformation of frontline customer service at Barclays through distributed digital innovation.

5. ANALYSIS OF DISTRIBUTED DIGITAL INNOVATION

This chapter presents an analysis of the radical transformation of retail banking at Barclays. Specifically, it addresses the agency dynamics of this transformation as a process of distributed digital innovation. In order to focus the analysis to support both the methodological and theoretical contribution targets of this thesis, each analytical step is presented by first explicating the analytical techniques used, after which the corresponding analytical findings are described in detail.

5.1 Analysis of Organisational Transformation

This section first describes the analytical process of identifying path creating actions and organisational transformations in the BankApp trajectory before presenting a thick description of the case history resulting from this analysis. The goal of this first analytical iteration is to generate narrow conceptual map of the case history and present salient organisational transformations, critical events and key actors.

5.1.1 Coding Critical Events and Organisational Transformations

As the goal of this first analytical step was to build narrow concepts describing the case chronology, I first familiarised myself with the case material from the perspective of the research question by conducting a micro-analysis of the collected data coding any meaningful unit related to the case history. This way the data was coded using open coding until semantic saturation (Strauss and Corbin 1990) was reached and a deep and textured understanding of the case context was obtained (Silverman 2010). This produced an extensive list of micro codes that gave a broad overview of the case context.

The next step was to identify and describe critical events containing the elements of micro-level actions; proposition, opposition and controversy, relating to organisational transformations throughout the case history from the initial coding. Following Prior (2008), key documents, such as i.e. design proposals and strategy briefs, were used to relate critical events allowing identification, description and comparison of critical events in the data. Each critical event in the case history was then described in detail drawing on both interview, document and observational data (Bowen 2009). This resulted in an abstracted sequence of 14 events outlining the case history from the experiences of the actors involved.

In order to provide sufficient context to each tension I drew inspiration from the controversy mapping approach (Latour 1991a; Venturini 2009) and generated a table with events on the vertical axis and actors on the horizontal axis. Specific micro-level actions were then coded onto the table in the form of agency of specific actors during specific events in the case history. Agency representing incumbent and emerging structures were colour coded to reveal the fault lines in the innovation process where controversies emerged.

Finally, I mapped critical events of significance to the innovation process identified in the data as an episode of organisational transformation. This way, it was possible to describe the process by which radical transformations at the organisational level emerged through a series of distributed actions.

5.1.2 Radical Transformation of Retail Banking at Barclays

In February 2014 Barclays implemented a radical reorganisation of the branch network across the UK. More than 1,600 branches had been changed or were in the process of a complete functional and visual transformation. Equipped with mobile devices installed with a new digital banking system, branch staff had moved out from behind the counters and onto the bank halls and even shopping centres and sporting events.

Transactions were migrated from manned counters to self-service channels such as web and mobile banking apps and newly developed self-service machines capable of processing even complex transactions without the involvement of branch staff. A branch manager reflected on the consequences of customer service transformation noting that before the transformation *"…cashiers balance their own tills, they have a safe with money in it, they have top drawers with money in. They've got glass in front of them and they do cheque processing."* He further reflects that after the introduction of mobile and self-service technology *"…they'll have an iPad instead of a desktop so they move from behind the computer out into the bank hall with a portable device."*

Despite the clear initial vision from senior executives for migrating transactions to self-service channels, the radical digital transformation of customer service came about in a piecemeal fashion where the actual organisational change was not predefined by a team of managers or designers. A senior area manager describes the emergence new customer service in terms of how multiple localised changes: *"...snowballed and fell over each other and built momentum."* This process in which multiple distributed actions combine to affect the radical transformation of frontline customer service at Barclays dramatically transformed the essence of retail banking including the function, layout and organisation of physical branches. A senior frontline support manager observes:

> *"And that's where the role [of the branch] is changing, and I can see actually counters disappearing but [the bank will] still have the offices and the advisers available, cashiers in my opinion will morph into all being mobile personal bankers."*

Figure 13 shows the newly introduced branch layout. Instead of tills and counters, the main features of the new design consist of a self-service machine for handling transactions and a number of meeting spaces customised for business meetings or private consultations with personal or business bankers.

Figure 13. Transformed branch layout

While these radical changes to branch layout and staff roles were immediately apparent, what enabled them was more elusive; the gradual development of a digital mobile banking platform that eventually comprised all the necessary functionality to service customers, even outside physical branches. A branch manager describes the new platform as follows:

> *"So basically it's almost like a branch without walls. So, you've got people that can go anywhere at any time and service customers."*

The following sections present analyses of each of the identified events in sequential order to establish their relation to organisational transformations that radically transformed retail banking at Barclays.

5.1.3 Sequence of Organisational Transformations at Barclays

The process by which mobile banking evolved took place through multiple distributed actions that combined into new technical as well as knowledge related and organisational transformations.

The totality of these events in turn invoked a series of significant organisational changes. Figure 14 outlines the five major organisational transformations within the 22-month period from August 2012 to June 2014. Within this period, I identified 14 critical events in which micro-level actions taking place at various distributed locations at Barclays combined to affect episodes of organisational change.

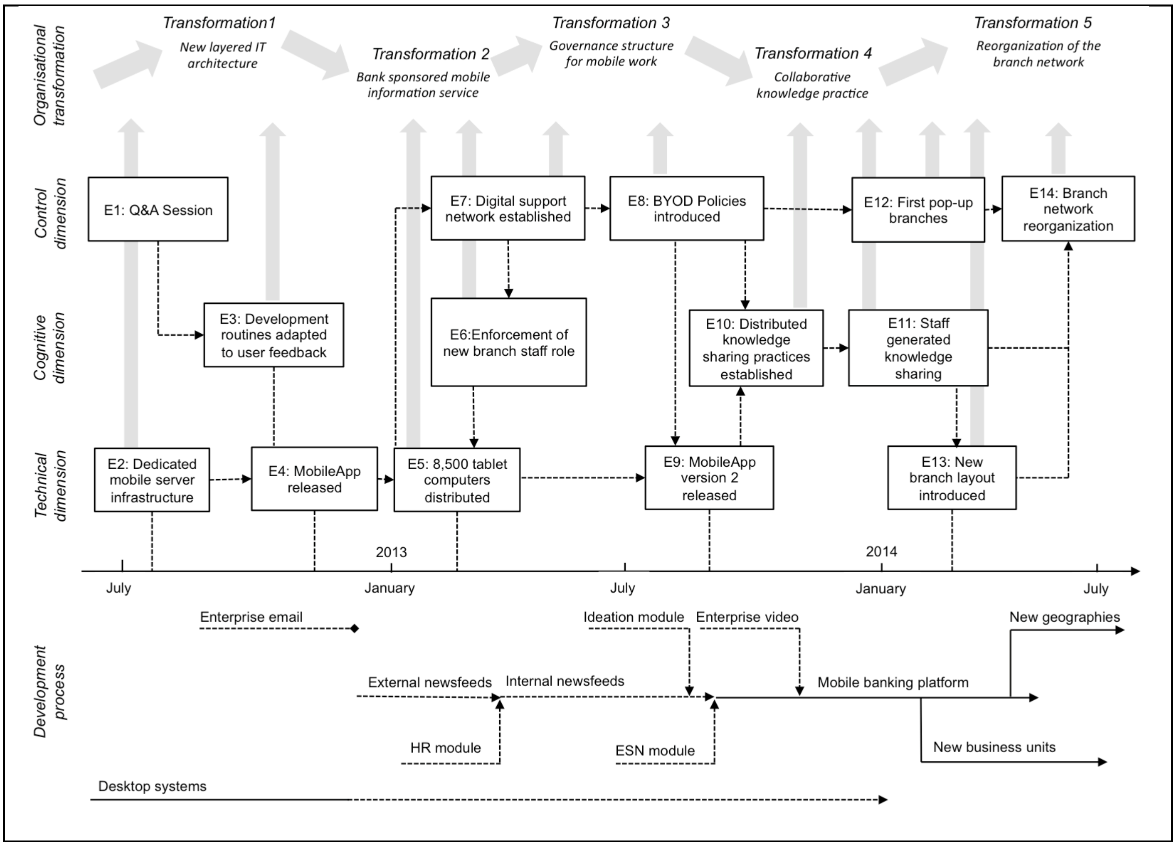

Figure 14. Chronology of organisational transformations

The remainder of this section reviews the chronology of events that led to the emergence of organisational transformations in the innovation path of BankApp over a two-year period. As this description cannot claim to be exhaustive, it focuses on providing an outline of the most important organisational transformations. This is achieved by exploring how organisational transformations emerge through micro-level actions affecting technology, knowledge and organisational control dimensions of the innovation trajectory.

The longitudinal analysis of the qualitative data allowed me to link micro-level actions with a number of accumulation events, which are outlined in figure 14. The diagram paraphrases how the impact of multiple events at one or all of the three innovation dimensions (i.e. technology, knowledge and control), combine into radical organisational transformations.

The non-linear sequence of events taking place in diverse contexts across multiple dimensions suggests that organisational transformations emerged through a multitude of distributed episodes rather than as a deliberate and pre-planned design or management decision. This distributed characteristic is further illustrated by the way in which the development of the BankApp project produced profound effects on existing technological, knowledge and control related domains e.g. by including existing technologies as modules or features, reformulating knowledge production practices and policies in the context of BankApp and orchestrating new organisational structures.

The first organisational transformation consists of the emergence of a new layered architecture, the second discusses the impact of distributing bank sponsored mobile devices, and the third organisational transformation results in the implementation of a governance structure for mobile work in the bank and a shift towards employees using their private mobile devices at work. The fourth transformation relates to a change towards a more collaborative way of working in the bank, and finally the fifth organisational transformation reports on the implementation of a new branch layout and organisation of the branch network. In summary, I produce a table that characterises each outcome and its impact at technological, knowledge or organisational levels, as well as the overall innovation trajectory of the project.

Transformation 1: New Layered IT Architecture

During the process of initiating the transformation in June and July 2012, branch staff was increasingly disconnected and disengaged resulting in high churn and apparent resistance to the transformation process from parts of the branch and support staff in retail banking. During the initial stage of the project it became increasingly apparent that growing tensions between the increasing demands for flexibility, speed and transparency and existing technological, governance and management structures, traditionally in place as a means of ensuring high levels of security and regulative compliance, where causing controversies in multiple organizational contexts from customer service to legal affairs and IT operations.

Over the summer of 2012 branch and regional managers began to invent new communication channels including print-outs of news bulletins and local staff meetings to keep their staff up to date about new developments and changes to internal processes and mitigate eventual concerns. Common for these channels was that, while resource intensive both in terms time consumption and material costs and therefore also sporadic and fragmented, they provided local management with valuable feedback from branch staff. Eventually, in June 2012, Barclays retail banking executives decided to invite all UK retail banking staff to take part in an online Q&A session (E1) to identify issues and solutions going forward:

> *"…basically it was like a melting pot for ideas that any member of branch staff could put their ideas forward and a recurring theme was that colleagues wanted to be able to access information in a relaxed way, …they wanted something that they could put on their iPhone or their iPad or their Android device so that they could see the best bits of Barclays systems at leisure. So an app for themselves to use. And that was the idea that created as [BankApp]." – Personal Banker*

Due to technical and security issues in providing branch staff with email accounts and the lack of personal desktop work stations, some 18,000 customer service staff members distributed across 1,632 branches were essentially left without access to personal digital communication channels and relied mainly on printed information provided and distributed by retail banking headquarters and the corporate intranet, which they had difficulties accessing due to lack of personal workstations. This meant that they were increasingly unable to keep up with the pace of new information regarding changing customer service practices, procedures and products. One frontline support manager explains the issues involved in disseminating information to the distributed branch staff via the corporate intranet site:

> *"If we try to cascade that [information] just through the intranet, which is what they did initially, a majority of staff wouldn't have picked up that intranet article because they don't physically go on and read everything."*

As a result, a project team consisting of staff with extensive customer facing experience was assembled to develop a new digital app as a replacement for corporate email, which for security reasons was found to be an unviable solution. The team formed soon began to design, develop, and implement all the apps and services that would ultimately transform frontline customer service in the bank. The newly established team soon realised that the scale of the project went beyond creating a new app as an information channel to radically transforming the ways with which branch staff serves customers.

One of the most immediate points of contention faced by the project team during August of 2012 was that BankApp relied on information shared from a wide range of data sources, not all managed centrally from Barclays' existing IT infrastructure.

When designing BankApp's mobile infrastructure, the issue of information security risk immediately emerged as access to secure information would be from personal devices rather than from traditional computing infrastructure provided and managed by the bank. This was perceived by the IT Security and Information Risk Management teams to change established patterns of risk which led to controversies between the stakeholders regarding what would be an appropriate approach to address this issue.

The project team's initially proposed design for an underlying infrastructure for BankApp was therefore rejected by IT Security managers as it would create a back door to the bank's mainframe system by connecting mobile devices through the open mobile data network. Internal developers refused that it was viable option to create a secure connection from the mobile application to the bank's monolithic data repository.

In order to move on with the project, the design team needed to come up with a fundamentally new solution. They involved key developers to craft multiple alternative design proposals, which were all rejected by IT security and information risk managers as insecure or excessively exposing confidential information. Finally, a budget was secured from top management for a solution that diverged radically from the previous server infrastructure and architectural logic.

The result was a design that divided Barclays's data into categories based on their level of confidentiality and separated each category on a dedicated server infrastructure (E2). This design meant that colleague information and customer data were managed separately and placed in separate server stacks. Therefore, colleague information could be accessed through the native mobile app without compromising the security of customer data. Ultimately, this led to the creation of a new layered modular IT architecture for the mobile platform and the decomposition of the single server infrastructure into two separate platforms, each with its own architecture and design logic, as a project manager explains:

> *"So we had a stack of all the servers with all the customer information on them, which is I mean so tightly guarded it's unbelievable. And what they said was: 'We cannot let people with their personal devices go through to that.' Simple. So we went: 'Ok, we'll build an image of that, and we'll call it the colleague stack.' And so any future apps and any future development for colleagues' development will be on this stack."*

Figure 15 shows the new architecture based on a layered modular design, which enabled service-device and content-network independence by providing a secure mobile gateway to access various services through mobile devices connected to the internet via Wi-Fi, 3G and GSM networks.

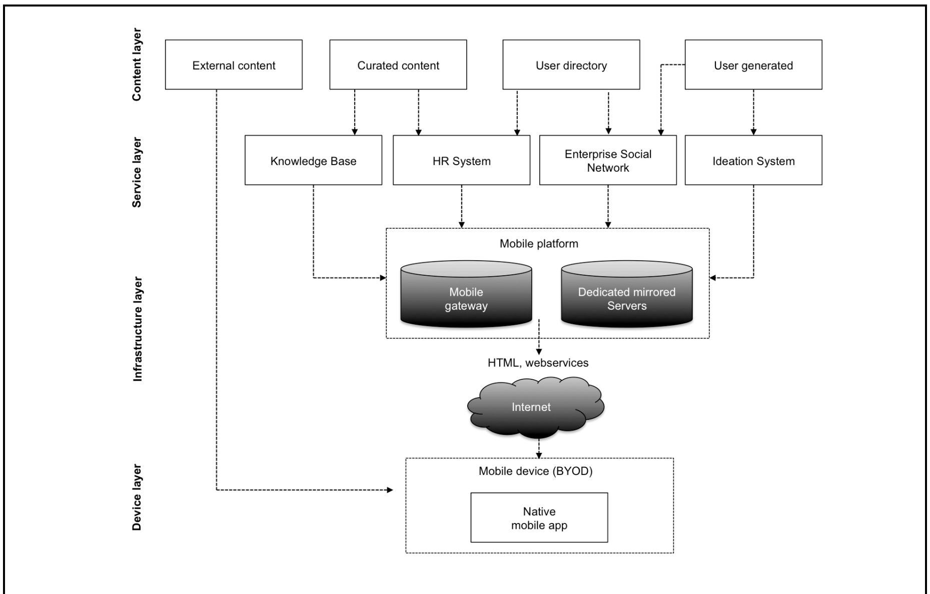

Figure 15. Layered modular server infrastructure

The result was an infrastructure where knowledge services could now be accessed from any device supported by the native app including tablets and smartphones, and where internal content from within the bank and external sources could for the first time be combined in the same system.

The new dedicated server infrastructure also enabled future mobile applications to be developed in a separate environment free from the security constraints and policies associated with the existing mainframe infrastructure. As such, it laid the foundations for a fundamentally new range of technologies to be implemented in Barclays. The goal of developing new technology had shifted from security and regulative compliance to responding to the needs of branch staff in servicing customers.

During October and November of 2012 these new objectives lead to the implementation of revised development routines (E3) including the implementation of a new ideation service on the corporate intranet where staff could suggest new features and services. The development lead explains how incoming suggestions were processed:

> *"So first we sort out the quick wins, all right, and we don't have to think too much about those. So if they are simple and easy, we have already made some provisions as I told you. … But there are things, which involves more time in getting the app, to get it created. So those will go into a change request, it goes back for review, it will then be goings through various reviews, forecasts, et cetera before it can be made into usable functionality."*

Whenever a request was made that was not readily mendable, a series of negotiations in which the new proposition was documented, sent for review with appropriate stakeholders in turn, criticised and revised until finally taking on a viable shape. Each proposition mobilised a specific network of stakeholders across the organisation including branch staff, developers, IT security professionals, project team members, legal staff etc. that shaped it and eventually accepted or rejected each functionality and process implemented into BankApp.

Transformation 2: Bank sponsored mobile information service

In the course of a four-month period, this process had generated enough serviceable features that a working IOS app had been developed. Because of ongoing negotiations between the project team, IT security, information risk management and legal teams regarding the nature of content to be published, the initial version of the app exclusively featured newsfeed from external facing websites for a period of five months until April 2013. However, as the BankApp platform supported the overall strategy, senior management supported and promoted its early introduction.

On December 12, 2012, the first iteration of the app was released (E4). During the first two months after BankApp was released it was downloaded more than 11,000 times. Due to numerous, and often conflicting, request by frontline staff and managers, a prototype pilot test was run in two branches in Manchester and London during October and November 2012 to test the applicability of developed functionality in a live setting before its wider release. This initial pilot test showed a need on the side of branch staff for a much greater variety of functionality than was originally planned for the first release. However, due to accumulating opposition from multiple other stakeholders within the organisation, the initial version was limited to four news feeds.

"…there is a huge list of different people we need to get to sign off, as well as HR who also has their bit to say. But all these teams came to an agreement to say 'within these new feeds, there is nothing within these news feeds that can't be shared elsewhere, so there is nothing that we're worried about so if it gets into the wrong hands… well they will have no excuse"

The content shown in the app was negotiated with legal, IT security and information risk management teams to make sure content complied with existing policies. The controversy revolved around the nature of the content served through the app and made accessible to employees from corporate or private devices. Existing information security policies distinguished between internal and external information, so the mobile BankApp blurred and transcended the previous information categories. These controversies also led to the transformation of the app's design and restricted the earliest version to providing external confidential information.

This way the initially released version was shaped as a synthesis of multiple micro-shifts between diverse stakeholders within Barclays. While this process ensured that the released BankApp system complied with security, legal and HR standards, the compromise was to some extent detrimental to the usefulness of the app for customer service in the branch network.

In February 2013, the extensive adoption combined with increasing pressure from customers to receive help using the mobile banking, payment and cloud storage apps offered by Global Bank, resulted in a decision from management to distribute 8,500 tablet computers to key staff within the branch network (E5) to accelerate adoption of BankApp across Barclays.

The acquisition of 8,500 tablet computers immediately drew news headlines and sparked enthusiasm from numerous stakeholders across the Barclays organization. The tablet computers reinforced the self-image held internally of Barclays as a digital leader in the financial services industry. Across the bank employees expressed support for the initiative with digital sceptics continuing to voice concerns although without mobilizing actual resistance. As a senior executive in the Barclays retail banking division reflects:

> *"…we quickly realized that our colleagues' attitudes to digital ranged from reluctant to enthusiastic and had people complaining about things like corporate coloured covers.*
>
> *We realized that what makes a difference to colleagues' attitudes is one-to-one interactions."*

Most of the bank-sponsored devices had very little or no impact on the transformation of customer services. Firstly, because despite the impressive numbers they were still too few to supply most of the circa 18,000 branch staff with adequate access and secondly, despite all intentions, many tablet units stranded in the offices of branch managers to whom they had been sent or with the most engaged staff members whom were already knowledgeable of the new services and familiar with digital technology in general. This episode made it clear to top management that technology in itself would not be sufficient to disseminate the level of transformation that had emerged in the most innovative parts of the organisation.

Episode 3: Governance Structure for Mobile Work

What started out as a project to implement a replacement for email to keep branch staff informed about updates to retail banking services had evolved into a transformation of the actual service provided to customers. As the technological barriers had dissolved, the main sources of opposition now related to governance and organisational structures.

In the course of the migration of transactions and the digitalisation of employee communication channels, controversies persisted within the group of branch staff, as the changes to their role were increasingly being enforced by management (E6):

> *"... there's a big split now between people who have bought into the new way of doing things and are really eager and keen and enjoy talking to customers and enjoy the freedom that they're given, but there are a lot of people who are out of their comfort zone with it and I think they will have to make a choice." – Regional manager*

On November 14, 2013 Barclays announced redundancies for 1,700 branch staff. The majority of these were managed through a voluntary redundancy scheme. However, this sent a signal to employees at all levels of the organisation that the digital agenda was by no means a fad that could be ignored or suppressed. Still, some remaining branch staff expressed concerns that they were not adequately trained to make the transition do mobile banking.

As a response to staff concerns and a slowing rate of adoption for BankApp beyond the first few days of use, a cross-organisational support network of digital ambassadors was established in February 2013 (E7). Digital ambassadors were tasked with visiting local branches to engage with branch staff encouraging them to transition to BankApp and mitigating any technical, competency related and organizational barriers to adoption. As a senior executive expresses it:

> *"…banks are basically organized like an army. The [digital support network] have broken out of that army structure to create connections across the organization."*

Initially there were only a handful of digital area managers in the support network, but as more staff was recruited by the end of December 2013 around 5.000 digital ambassadors had educated 12,000 branch staff with the purpose of upgrading digital skills across the bank. A regional digital manager responsible for some 80 branches explains how this scale of the digital support network:

> *"And if you are in branches you can tell they're just not at the level where they [branch staff] need to be with digital. So they hired us to go in each branch to spend a day there at the beginning in each branch and recruit more [digital ambassadors]."*

The digital support network quickly identified several governance-related barriers to adoption where new digital BankApp supported customer service practices and incumbent governance structures collided. In some regions, local managers and legal staff had formulated policies banning the use of personal devices during business hours. Other examples include some cases of employee contracts stipulating restrictions to the use of mobile technologies, and legal terms and conditions for system use explicating severe repercussions in a number of specific scenarios of misconduct.

This governance logic was based on an existing institutional categorisation of technology-supported activities as being either internal, i.e. work related, or external belonging to the personal domain. The introduction of a work-related app on personal mobile phones or tablets challenged the existing logic within Barclays, which led to requests to reformulate some of the prevailing governance principles in the organization. A digital ambassador explains how this resulted in initial resistance from some employees:

> *"… the biggest point of resistance is perhaps just using it on your personal phone… But then once they understand the benefit of having the app there's no barriers there, then they're sort of overcome with the pros that outweigh the cons. But I think the initial thought is just reluctance to putting it on their own device."*

The result was an introduction of a Bring Your Own Device (BYOD) policy allowing staff to access and produce previously internal information from their private mobile devices as well as to bring company devices home (E8). In addition to boosting adoption of BankApp, these new policies sent a clear signal from top management that a new modus operando for the retail bank embracing a more flexible and less regulated regulative setting within the bank. An illustration of the new governance model is that after this point, rather than formulating a new policy document, the project and legal teams scheduled weekly meetings in which to coordinate specific issues and integrate policies in the mobile platform.

By September 2013 the project had evolved into a new digital platform providing access to news feeds, a knowledge manual, and ideation platform, location services, access to HR services, a personal dashboard, enterprise videos and aggregation of social media streams. All of these services were meant as a way of empowering branch staff to provide a better service to customers, as well as to keep them more informed and engaged with organisational news and information.

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Episode 4: Collaborative Knowledge Practice

The introduction of new services in BankApp version 2 (E9) and enforcement of new governance structure meant that both technological and organisational barriers for adopting the emerging digital banking paradigm had been removed. The period following September 2013 saw a groundswell of new knowledge practices being adopted throughout the Barclays organisation.

By the end of 2013 the mobile BankApp provided a platform for information exchange and collaboration through the introduction of more collaborative services (E10). This included the integration of an existing enterprise social network (ESN) where all staff members could create groups for specific topics, processes, areas or fields of interest to interact across geographical and organizational boundaries. Due to the difficulty of access for the majority of retail banking staff without a dedicated desktop computer, the ESN had so far had little activity besides in groups that were explicitly relevant to staff working in headquarters.

In combination with a newly developed ideation service where staff could suggest improvements to work processes, organisational structure and supporting technology and a platform for video sharing among employees, the integration of social capabilities on the mobile BankApp infrastructure created a platform on which branch staff could connect and collaborate. One branch manager refers to this new context of collaboration as a *"...new social conscience*" within the bank. A regional digital manager explains:

> *"So I think that's how it works, that's how they fed each other. You've got the [subject matter experts], you've got this network that are kind of on the same page and then you've got the community, which sits on the [Enterprise Social Network] which is where our consciousness sits. If you want to access that you can see what's inside the heads of the [subject matter experts]. And then that's fed through [BankApp]."*

The synergy emerging between support network, enterprise social network and BankApp had resulted in the emergence of a new knowledge sharing practice in which access to specific resources across previously separate contexts could be accessed from anywhere within the organisation.

In February 2014, the digital support network launched a campaign to encourage the emergent knowledge sharing practices. This lead to a situation where some branch staff members with expertise in a specific process or topic would provide content in the form of videos, presentations, articles and updates on the ESN to share information and interact with all users anywhere they might be. This user-generated knowledge across geographical and organisational boundaries ushered a new culture within the bank where innovation of technology, processes and services was transparent and distributed throughout the branch network (E11):

> *"But also not only the horizontal communication but actually by just putting #[customer mobile app] you are interacting with the owner of mobile banking or [customer mobile app]. So you can use that, so you can say I've got a problem and there's a person who can solve that problem. He's aware of it straightaway and can react." – Personal banker*

It also opened a continuous flow of requirements from branch staff and support network members resulted in the release of additional functionality and services that linked to other systems available in the bank ranging from collaboration and communication systems such as the existing knowledge base platform, and the personnel records system provided by the human resources team.

Episode 5: Reorganisation of the Branch Network

With the emergence of new collaborative knowledge practices, several ideas pertaining to a reorganisation of the branch network surfaced on BankApp. Several of these suggestions were discussed and developed collaboratively by branch staff and retail banking managers using BankApp. Many of the most substantial suggestions revolved around how to leverage BankApp to deliver new and innovative banking services.

By November 2013 the radical transformation of customer services where BankApp enabled direct engagement with customers lead to the introduction of Barclays popup branches in shopping centres, at sports venues and small villages without a branch at regular intervals (E12). These transformations were seen as a physical manifestation of the customer focus strategy to move branch staff from high street branch locations to a *"... branch without walls. So you've got people that can go anywhere at any time and service customers".* Consequently, branch staff started moving out of the physical branches and into busy shopping centres and sporting venues on weekends. This allowed them to engage with customers

Already from June 2013 two branches had piloted new self-service technology and branch layout designed to migrate transactions to customer operated channels and free up branch staff for consulting around more complex issues. As one area manager explained at the time:

> *"…these are known as the branch of the future. So these are branches every staff member has an iPad. And they're all connected to each other, and they are all connected to your account, so if you walk in they can just slide along your card, you can get access straight away and pretty much you can do anything one-on-one with an iPad"*

During the first two quarters of 2014 another 170 branches had transitioned to the new layout and the remaining branches were scheduled to follow over a two-year period (E13). In total, by the end of the case history in May 2014, more than 1,600 branches had been or were in the process of a complete functional and visual transformation.

In February 2014 Barclays announced the radical reorganisation of its retail banking network across the UK (E14). The branch network was reorganised from large, hierarchical areas to smaller interconnected retail communities serviced by interconnected hub and spoke branches each specialising in a different set of services tailored specifically to their local environment.

Specifically, the branch organization was restructured from relatively areas of about 30 branches to smaller more local communities of five branches with a leading 'hub' branch servicing more agile and even mobile 'spoke' branches depending on the specific geographical location. The BankApp mobile platform, that started as a newsfeed to save printing costs, had now evolved into a backbone for the complete reorganisation of the branch network and radical transformation of customer service.

Having reviewed each case event in conjunction and described how they each relate to organisational transformations, I can now move on to summarise the evolution of BankApp. Table 9 summarises how each episode of organisational transformation emerges from a series of distributed events.

Table 9. Events and Organisational Transformations at Barclays			
Organisational transformation	**Critical events**	**Affected dimension**	**Description**
T1. New layered architecture	E1: Q&A Session E2: Dedicated mobile server E3: IS development routines adapted to user feedback	Technological	New dedicated mobile server infrastructure designed and implemented
T2. Bank sponsored mobile information service	E4: BankApp released E5: 8,500 tablet computers distributed	No outcome	Too few units available and units strand with digital natives and have little or no impact on customer service
T3. Governance structure for mobile work in branches	E6: Enforcement of new branch staff role E7: Digital support network established E8: BYOD Policies introduced E9: BankApp version 2 released	Organisational	Retail bank management enforces BYOD policies after initial governance model was rejected by legal and information security teams The new governance model was reinforced by the establishment of a support network of digital ambassadors throughout the branch network
T4. Collaborative knowledge practice	E10: Distributed knowledge sharing practices established E11: Staff generated knowledge sharing	Cognitive	Distributed ideation of banking services and user-generated knowledge sharing across geographical and organizational boundaries
T5. Reorganisation of the branch network	E12: First pop-up branches E13: New branch layout introduced E14: Branch network reorganisation	Organisational	Branch network restructuring into communities with ‘hub’ and ‘spoke’ branches with additional pop-up branches

As shown in table 9, each organisational transformation is associated with multiple critical events in which micro-level actions accumulate. Reviewing the list of actions for each organisational transformation reveals how specific events are not confined to a particular organisational departments, functions or domains, but are distributed over a wide range of organisational contexts. These contexts are analysed in greater detail in the following section.

5.2 Analysis of Innovation Networks

This section analyses the innovation networks around the BankApp trajectory using social network analysis of the digital trace data. The network analysis first identifies the context of the innovation network of the entire case history to generate an overview of distributed contexts and actors. It then moves on to analyse the evolution of the innovation network by repeating network analysis for each period of organisational transformation. The outcome is a comparison between the innovation network structures relating to each transformation providing insights into the evolution of the innovation network over time as well as the relation between innovation network structure and organisational transformation.

5.2.1 Analysing Innovation Networks

To generate an overview of the distribution of the entire process, I first generated an innovation network using digital trace data (Wasserman and Faust 1994). Each connection between two actors was represented as an interaction with a sender and a receiver exchanging textual communication. As the digital traces were extracted from an internal project work group related to the BankApp project, each interaction can be assumed to pertain to it with some relevance.

The raw data set was formatted in tabular form with each row representing a single interaction identifying time stamp, author, affiliation and text body. This data was restructured as an edge list with a source and target node, and a table listing the attributes for each node using a Python script. Sources were identified as the author for the interaction and target nodes as actors that were directly addressed in the text body using the '@' character (Prell 2012). This function means that, although visible to all actors on the network, each specific interaction generates a notification for a specific user or user-created entity. From this edge list, a network graph was generated using the social network analysis package 'statnet' for R (Handcock et al. 2008). The graph was created as a uni-partite actor network representation of the innovation network as described in section 2.4.3. This allowed for analysis of the actor composition and distributed innovation network contexts for the entire innovation network.

Dividing and analysing the network data relating to each organisational transformation separately, and then comparing the results longitudinally across the five episodes of transformation, provided a longitudinal analysis of the evolution of the innovation network. A number of statistical measures were used to analyse the innovation network relating to each organisational transformation (Prell 2012; Scott 1988; Tichy et al. 1979; Wasserman and Faust 1994). Each of the metrics used are described in turn below.

Network density measures the coherence of the innovation network in terms of number of interactions between actors. Network density D is calculated by dividing the number of edges, or connections, in a network E by the total number of possible edges Ep.

```
D = E/Ep
```

The total number of possible edges Ep can be calculated by multiplying the number of nodes in the network N by the number of nodes minus one, with N-1 representing the number of possible edges for each node. In undirected networks, each edge counts only once, as no directionality exists that allows two nodes to be connected ‘both ways’. Therefore and the product should thereby be divided by 2. As the networks in this case study are directed, I will refrain from this last step and use the following method of calculating the number of possible edges:

```
Ep = N*(N-1)
```

Actor degree is defined as the number of connection to or from each actor in the network. For example, an actor with two outgoing and one incoming links will have a degree of 3. The density metrics shows the relative interaction activity in the network over time as it traces the degree of actualised interactions.

Network diameter represents the shortest distance between the most distant two nodes in the network. Computing the shortest path length from every node in the network to all other nodes produces network diameter. The network diameter is then the longest of all the calculated path lengths. The diameter metric analyses the coherence or effectiveness if you will of connections in the innovation network. A long network diameter indicated a fragmented network where interaction between clusters is sparse where a short diameter indicates better cross-network connectivity.

The *clustering coefficient* (Luce and Perry 1949) refers to the degree to which nodes in a graph tend to cluster together. The metric used at the global network level computes the number of closed triplets, or 3 times the connected triangles, over the total number of triplets, both open and closed. This gives a reliable indication of the degree to which nodes in a graph tend to cluster together.

Modularity is a measure of the strength of division of a network into highly connected clusters. Modularity is calculated by comparing the empirically observed network with a random network of similar size and represents the fraction of total edges of an observed network that fall within network clusters minus the expected such fraction of a randomly generated network. The value of the modularity metric is positive if the number of edges within clusters exceeds the number expected on the basis of chance (Boccaletti et al. 2007). A network with high modularity has dense connections between actors within locales but sparse connections between actors in different network clusters. Using modularity measurements I was able to detect distinct innovation network clusters within the global innovation network.

Having described the relevant analytical techniques and measures, I now turn to applying them in analysis of the innovation network at Barclays.

5.2.2 Innovation Networks at Barclays

As each of the organisational transformations described in the previous analysis emerges from multiple micro-level actions located in distributed and localised micro-level networks, I now move on to analyse the innovation networks relating to each transformation. The dual aim of this innovation network analysis is to characterise the actors involved in distributed innovation and their interconnections, and to describe the evolution of innovation network structure relating to organisational transformations in the BankApp trajectory.

By analysing relational data from the BankApp work group I was able to establish how specific organisational transformations emerged from specific micro-level contexts within the innovation network. First, I sampled all the relations created through directed interactions in the BankApp work group, i.e. measured when an actor addresses, informs or directs a question to another actor in the context of the BankApp work group. Each interaction is defined as an event where one actor addresses another regarding topics that are in some way related to BankApp.

The resulting innovation network represented 2,338 interactions between 1,038 actors as illustrated in figure 15. The BankApp innovation network exhibits highly diverse characteristics as it comprises of a number of different actor groups. Specifically, the nature of nonhuman actors represented in the innovation network stands out as especially notable. Actor types were identified by extracting information from the 'user' profiles of each actor and coding them into consistent categories. I then added this categorisation as meta data for each actor and repeated the network analysis.

This revealed an actor composition in which individual employees accounted for just 63.3% of the total number of actors. The remaining interactions were directed at geographical areas 17.05%, organisational or topical groups (10.31%) and technologies that made up 9.25% of the actors identified in the BankApp innovation network.

A closer investigation of the content of actual interactions reveal that individual human actors will routinely address nonhumans in relation to specific issues or propositions. This is illustrated in the following example of an interaction from the digital trace data between an employee and the BankApp platform:

```
     @[BankApp]: my phone will not recognise my registration
code how do I order another one. I am not the only person in our
office this has happened to.
      @[Employee]: Hi Kay, In order to get a new registration
code you must de-register yourself through the [BankApp]
[knowledge] page and then re-register. Thanks

     @[BankApp]: I've just sorted now after a load of faffin
round. Delete history and app and re-download should work fine.
```

```
@[Employee]: T0003 is an issue with the servers, we are
working at pace to fix this. In the meantime, please advise
users to delete the application then reinstall.
```

The most surprising aspect of this characteristics of the innovation network is perhaps that nonhumans are able to respond. By jumping into threads, other individuals are able to enact the role of nonhuman actors, in the case of the above example, the BankApp platform.

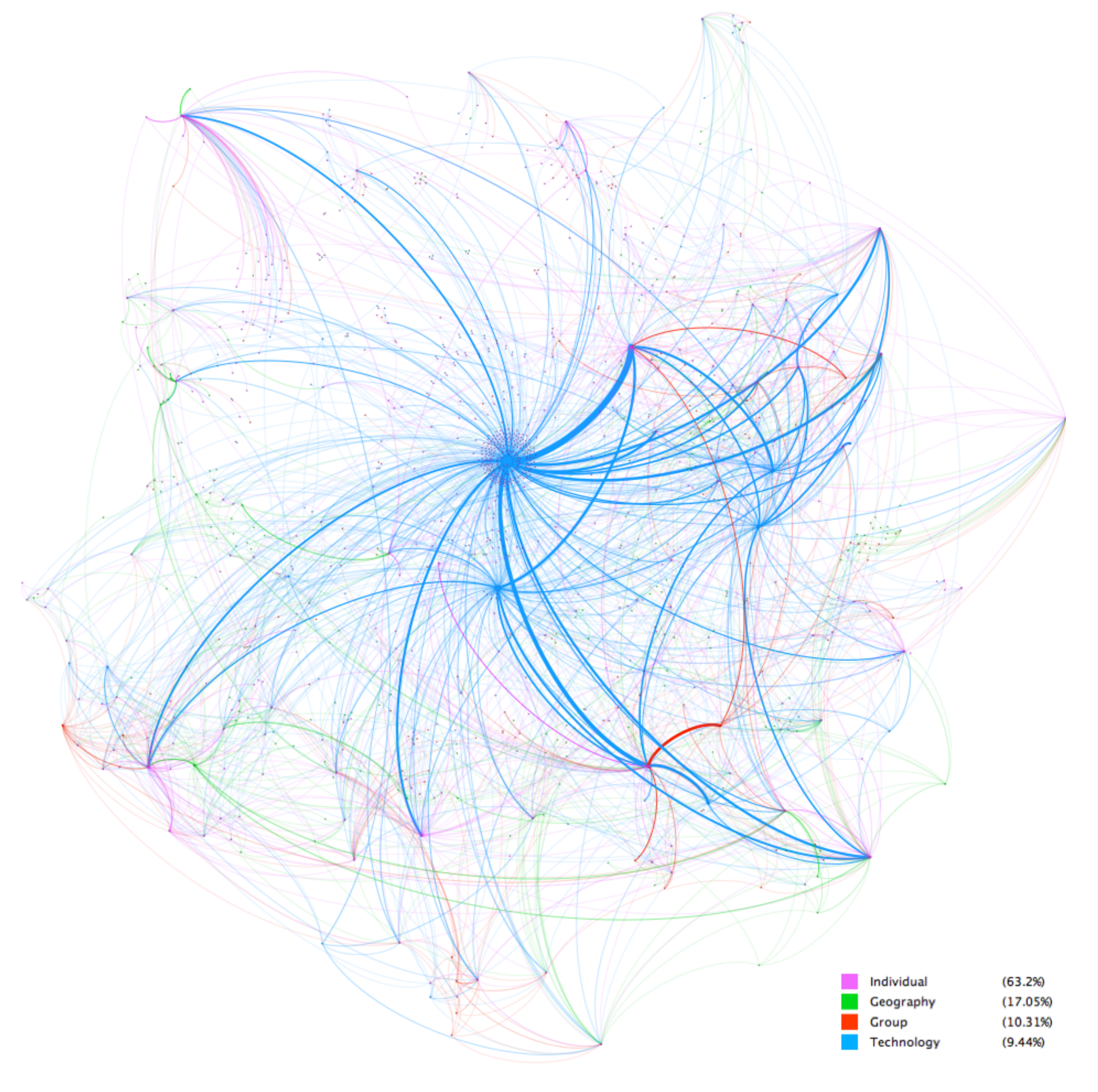


Figure 16. BankApp innovation network

While this characteristic of the BankApp innovation network to a large extent is due to the specific affordances provided by the digital work group system from which digital traces where extracted, it does illustrate the possibility of the emergence of enacted and algorithmic actors as key players in innovation networks.

Having empirically established the characteristics of heterogeneous actors that make up the BankApp innovation network, I now focus the analysis on its structure and distribution.

The initial network analysis detected highly connected micro-level clusters of interconnected actors in the innovation network. Specifically, 47 distinct micro-level network clusters, defined as densely connected and separate micro-level communities of actors, were identified. With a modularity of 0.436 compared to a modularity of 0.112 for a random network of equal size, the high modularity of the BankApp innovation network confirms that the innovation network is significantly distributed into multiple micro-level clusters.

The multiple micro-level clusters of the BankApp innovation network are illustrated in figure 17 where each micro-level network has been given a separate colour. The graph shows the largest micro-level network cluster comprising of 39.31% of the actors and the rest following a power law (long tail) distribution.

As human actors routinely addressed specific technologies, and to some smaller extent topics and geographies, the network represents the full range of socio-technical actors involved in and emerging from the project as the BankApp trajectory materialised. These actors are distributed in highly connected local clusters across the with distinct structural properties.

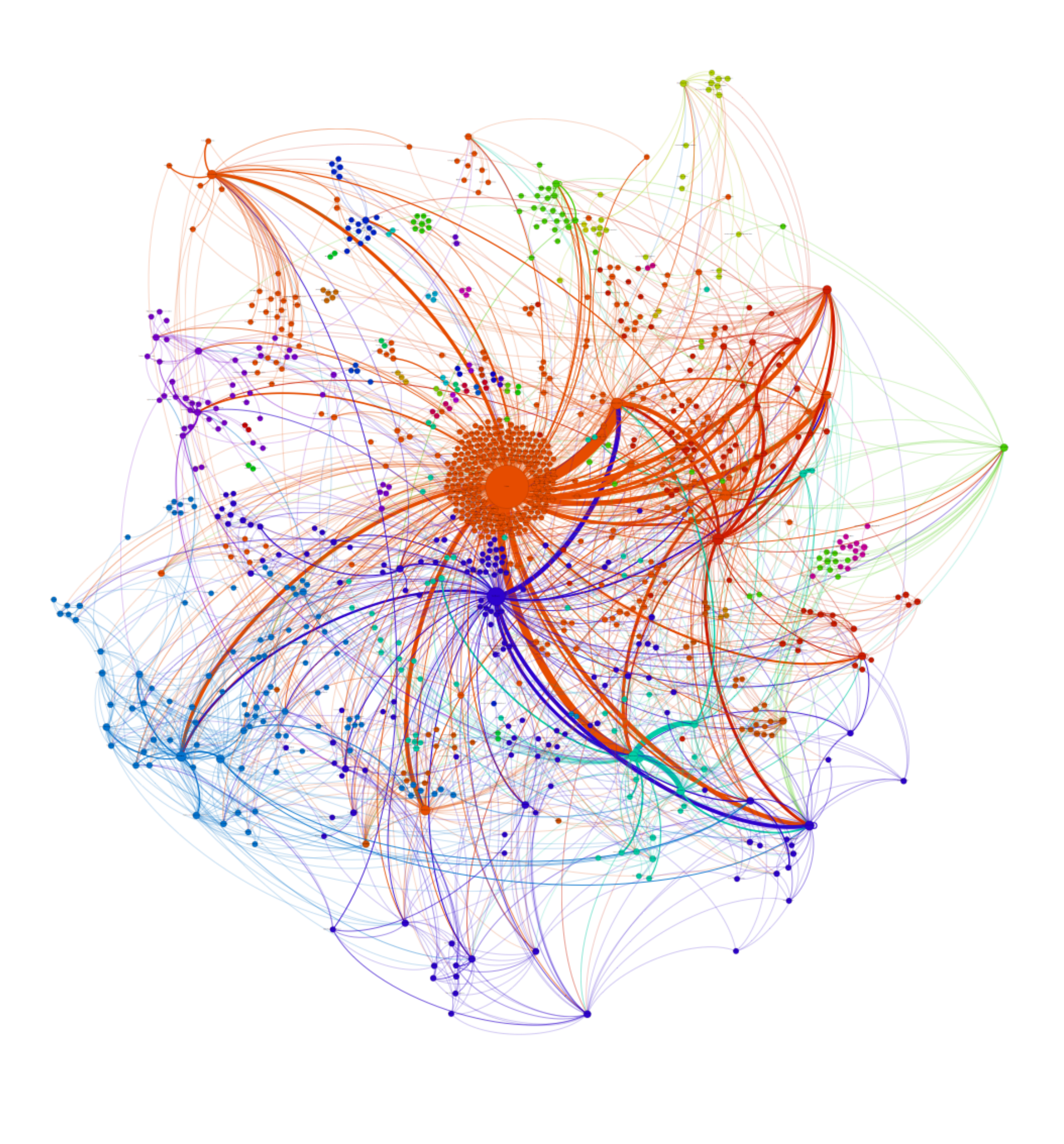


Figure 17. Micro-level innovation networks

Because the digital trace data where longitudinal we were able to trace the evolution of innovation network distribution over time. The following section analyses the relation between the distribution of innovation networks and organisational transformations throughout the case history.

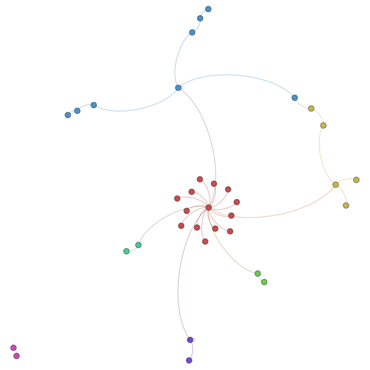
5.2.3 Distribution of Organisational Transformations

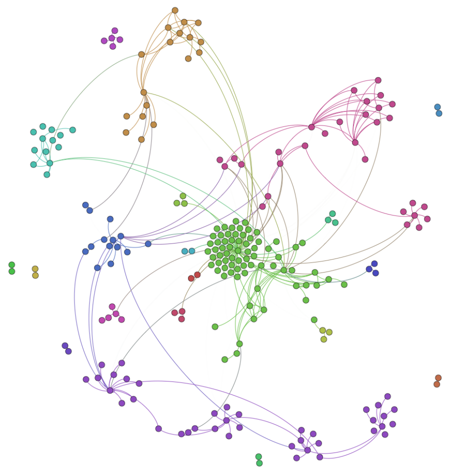
In order to identify the distribution of the innovation networks relating to each episode of organisational transformation, I split the digital trace data into separate data sets matching each period of organisational transformation.

The right-hand column in table 10 shows the innovation network for each episode of transformation where actors in different micro-level clusters are given separate colours. The table reveals some interesting patterns in the structure and nature of how the innovation network is distributed: The initial development of the layered server infrastructure for BankApp and the following development and launch of BankApp version 1 emerged from a relatively small and dense network with a central hub connecting a relatively small number of seven micro-level clusters.

In contrast, the distribution of large numbers of tablet computers to branch staff enlisted a multitude of actors from across the retail network organised into 14 locales. However, the qualitative analysis showed that even though the structure of the innovation network was significantly more dispersed, no significant actor group opposed the distribution of tablet computers why they had very little impact at organisational level. AS described in the case history, subsequent outcomes encountered significant opposition from large stakeholder groups.

This means they were able to mobilise an increasing number of actors in an ever more distributed innovation network producing radical outcomes in technological, knowledge and organisational dimensions.

Table 10. Innovation Network Evolution		
Organisational transformations	**Network clusters**	**Innovation network diagram**
T1. New layered architecture	7	
T2. Void (Bank sponsored mobile devices)	14	
T3. Governance structure for mobile work in the bank	12	

T4. Collaborative social conscience	21	
T5. Reorganisation of branch layout, functioning and organisation	29	

The significant distribution of the innovation network identified in table 10 suggests that the digital trajectory of BankApp emerged through interactions between increasingly distributed and highly heterogeneous actors, including individuals, technologies, groups and geographies, situated in multiple micro-level network clusters.

This leads the question of what are the agency dynamics by which organisational transformations emerge in increasingly distributed innovation networks. In the following section, I zoom in to empirically explore these distributed agency dynamics and the way in which they combine to affect radical organisational transformations.

5.3 Analysis of Micro-Level Agency Dynamics

This section analyses the transformational agency dynamics of distributed innovation. It first describes the analytical techniques by which micro-level agency dynamics was analysed before moving on to applying said techniques in an empirical analysis of the characteristics and dynamics by which distributed actions affected organisational change in the case of BankApp.

5.3.1 Measuring Micro-level Agency Dynamics

As the purpose of this third analytical iteration was to lay the groundwork a more formalised theory of distributed digital innovation, it applied concepts emerging from the previous iterations. This was done by first identifying through computational semantic analysis the micro-level interactions with transformational potential before applying computational clustering algorithms in combination with qualitative coding, and comparison to previous coding, to generate a typology of agency dynamics in distributed digital innovation.

Distributed actions are previously in this thesis defined as instances of proposition, opposition and controversy that reenergises and endangers established actor relationships at the micro-level. Consequently, the first task in establishing the agency dynamics of distributed digital innovation is to identify each micro-level interaction relating to one of these elements. This was achieved by applying latent semantic analysis (LSA), an algorithm often used in search ranking and digital image de-noising (Deerwester et al. 1990; Dumais et al. 1988). LSA computes semantic association between a set of documents and a list of specific terms contained within those documents (Deerwester et al. 1990). It works on the basic assumption that language utterances have a semantic structure, i.e. a certain form in their meaning. However, this structure is obscured by practical word usage containing noise, synonymy and polysemy (Landauer et al. 1998). One of the advantages of LSA is that it overcomes the problems associated with polysemy and synonymy, a feature that enabled me to measure relations between different semantic concepts related to path micro-level agency rather than simply comparing word counts (Landauer et al. 1998).

First, the data set was pre-processed the to remove noise and structure it in a way that would be compatible with the LSA algorithm. The raw text file was processed into a structured data matrix using a Python script. I then split the body text of each post into separate documents. Then, noisy words like 'the, 'a', 'an' etc. were removed using a standard English so called stop word list. The sanitised data was then subjected to word stemming to reduce each word to its syntactic core, e.g. 'controversy', 'controversies, 'controversial' were reduced to the word stem 'controver'. The resulting data set consisted of 4,234 unique and semantically relevant terms in 1,843 interactions.

From this a document-concept matrix of word frequencies was generated. As a first step in the LSA analysis, I generated a document-term matrix **W** of term occurrences in the collection of documents corresponding to the set of interactions. The document-term matrix containing term frequencies was constructed by counting occurrences of term n across a collection of documents d to give the $d \times n$

matrix **W**. A small section of the resulting document-term matrix of word frequencies derived from our analysis is shown in figure 18.

	D1	D2	D3	D4	D5	D6	D7	D8	…D1843
1. post	1	0	0	0	0	0	0	0	
2. and	0	1	0	0	1	2	0	0	
3. bank	0	2	0	0	0	0	0	0	
4. branch	0	1	0	0	0	0	0	0	
5. click	0	1	0	0	0	0	0	0	
6. communiti	0	2	0	2	1	0	0	1	
7. custom	0	1	0	0	0	0	0	0	
8. [confidential]	0	1	0	0	0	0	0	0	
…4430									

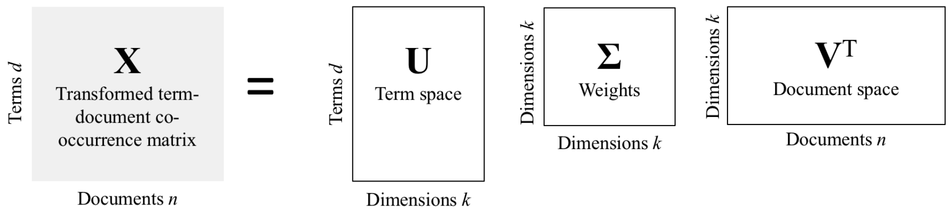
Figure 18. Section of a term frequency matrix

As a simple term frequency count does not account for practical language use such as synonymy and polysemy, I applied a weighing algorithm to the term frequency matrix. Following the standard LSA implementation I applied the Term Frequency – Inverse Document Frequency (TF-IDF) algorithm (Salton et al. 1975). This algorithm compensates for terms that are frequently used in common linguistic constructions and therefore should not be given the same weight as more semantically pertinent terms.

After weighing, the concept-document matrix produced by LSA can be used as a vector space model (Salton et al. 1975) i.e., as an algebraic model for representing text data as vectors of semantic concepts. This vector space model can be used to interrogate co-occurrences of concepts rather than terms in a given body of text.

The optimal number of dimensions in this vector space was computed using the dimcalc-share algorithm (Wild and Stahl 2007), which finds the first position in the descending sequence of singular values **s** where their sum (divided by the sum of all values) meets or exceeds the specified share. The semantic dimensionality was calculated using a standard share of 0.5. The algorithm determined that the information contained in the original term-document matrix **W** could be described by a matrix using 119 latent semantic concepts.

After this extensive pre-processing, it was now possible to apply singular value decomposition (SVD) to **W** in order to derive a low-rank approximation of the likelihood of a given term to occur in each document (Griffiths et al. 2007). To compute a rank k approximation, I reconstructed the term-document matrix **W** into a new matrix **X** by calculating the product of the two orthogonal matrices **U** and **V** and a third diagonal matrix **Σ**. Sigma is calculated as the square of the eigenvalues, or singular values, of the diagonal matrix. The Matrix **X** representing the latent semantic space is defined as $\mathbf{W} \approx \mathbf{X} = \mathbf{U\Sigma V}^{T}$, where the dimensions of **U** and **V** are $d \times k$ and $n \times k$, respectively, and **Σ** is a $k \times k$ diagonal matrix. The process can be illustrated as shown in figure 18 below.



Adapted from Griffith et al. (2007)

Figure 19. Singular value decomposition

As illustrated in figure 19, SVD can be viewed as a method for rotating the axes in k-dimensional space, so that the first axis runs along the direction of the largest variation among the documents, the second dimension runs along the direction with the second largest variation, and so on until the matrix dimension k is reached. A cross section of the resulting SVD matrix indicating the probability of each term to be semantically related a given interaction is shown in figure 20.

	D1	D2	D3	D4	D5	D6	D7	D8	…Dk
1. post	4.09	-0.01	-0.04	0.00	-0.02	-0.06	0.02	0.00	
2. and	0.01	2.17	-0.01	0.00	2.11	2.12	0.24	-0.04	
3. bank	0.02	4.84	0.00	-0.03	-0.01	0.10	-0.13	-0.03	
4. branch	0.02	5.39	-0.04	-0.05	0.03	0.04	-0.05	0.03	
5. click	-0.01	5.04	0.02	0.01	0.03	0.05	0.13	0.05	
6. communiti	-0.03	1.82	-0.05	1.79	1.81	0.09	-0.03	1.76	
7. custom	0.02	4.63	0.01	-0.06	0.00	-0.11	-0.04	-0.04	…n

Figure 20. Transformed term-document matrix

This new matrix **X**, shown in figure 19, was different from the original matrix **W** in that a single document-term weight can be positive even if it was not contained in that document, but if the document contained words with similar meanings. Furthermore, single document-term weight can have a negative value if the document contains words with opposite or negatively related meanings.

In order to determine the types of micro-level agency dynamics in the data, cluster analysis was applied using the open source statistical framework R (Meyer et al. 2008). Unlike alternative methods such as e.g. Polarity Inducing Latent Semantic Analysis (Chang et al. 2013), cluster analysis allows me to reduce the number of conceptual dimensions by semantic associations. This was achieved by running cluster analysis using the latent semantic space, the transformed term-document matrix **X**, generated from the LSA.

First, a search query containing terms associated with micro-level controversy such as “change”, “conversion”, “deviation”, “move”, “transfer”, “transformation” etc. was created. Altogether, the search query contained 89 terms related to micro-level controversies. From this search vector I identified terms associated with micro-level actions in the latent semantic space using cosine similarity measures. Having done this, the associated terms were added to a micro-level action vector used to reduce the initial semantic space to an action-concept space.

Applying k-means clustering to this action-concept vector space generated the initial grouping for a typology of agency dynamics. Given set of observations (picture a scatter plot of points), and a number of groups or clusters that you wish to group them in, the k-means algorithm finds the centre of each group and associates observations with the groups with the closest centre in terms of Euclidean distance.

In order to determine the optimal number of clusters in the data I followed the guidelines provided by Hothorn & Everitt (2014, p. 251) and plotted the sum of squares for each group to locate a bend in the plot similar to a scree test in factor analysis. The resulting plot shown in figure 21 reveals a ‘knee’ at five clusters indicating the optimal number of clusters in the data.

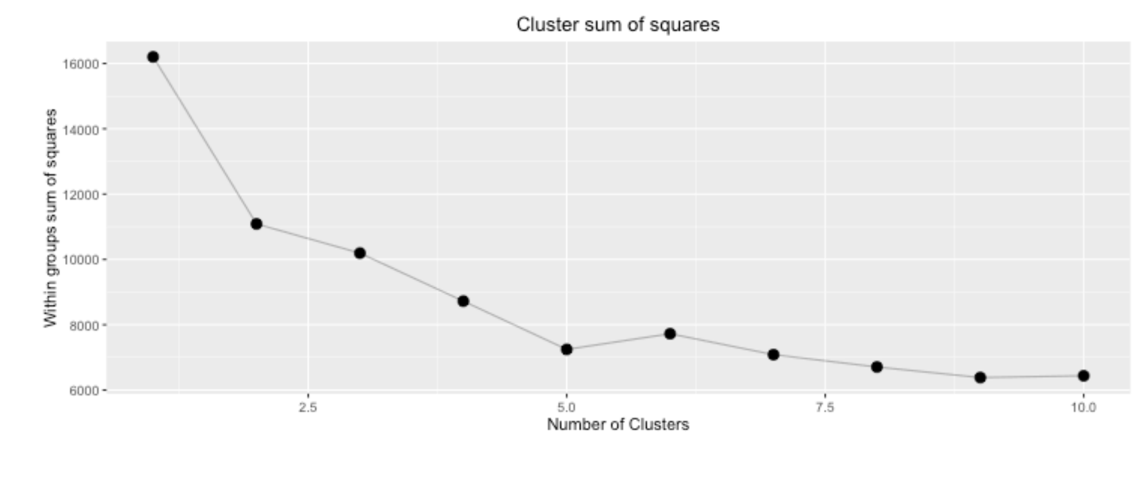


Figure 21. Number of clusters by within group sum of squares

The cluster analysis provided an initial list of codes representing semantically related concepts for each of the five clusters. By comparing with open coding from the qualitative study, a typology of agency dynamics was generated. The typology includes a description of each agency dynamics, specification of the affected dimension of digital innovation, and a explication of its impact on the general trajectory. The actual implementation of this method and resulting typology is described in detail in the following section.

5.3.2 Micro-level Agency Dynamics at Barclays

To identify the complex micro-level dynamics by which distributed transformations are created, I conducted a fine-grained semantic analysis of extensive digital trace data. I shall refer to such dynamics manifested in micro-level actions as digital agency dynamics. The analysis was conducted by taking an empirical deep-dive into each micro-level innovation network to identify the digital agency dynamics of each organisational transformation at the level of individual interactions using computational latent semantic analysis techniques. Inserting a predefined search vector derived from coding of previous interview, document and observational analyses revealed that digital agency dynamics manifested semantically as latent semantic patterns throughout the case history.

Specifically, 119 semantic dimensions related to micro-level actions were identified from the 1,937 individual BankApp workgroup interactions. In order to identify manifestations of digital agency over time, the similarity scores for each record using the highest score found in the document collection were normalised and the mean within group sum of squares for all records in a month was calculated. This provided a measurement for digital agency level indicating the level of use of concepts related to micro-level agency. Put differently, this measurement indicated the level to which micro-level agency is manifested semantically at each time interval.

The graph in Figure 22 shows a number of spikes in micro-level agency corresponding with each of the organisational transformations identified above. They are: 1) the development of the server infrastructure and initial launch of BankApp, 2) distribution of 9,500 bank-sponsored tablet computers, 3) introduction of the support network and BYOD policies, 4) the emergence of a new collective conscience in the wake of the release of the second version of BankApp, and 5) the restructuring of the branch network at month 15-17.

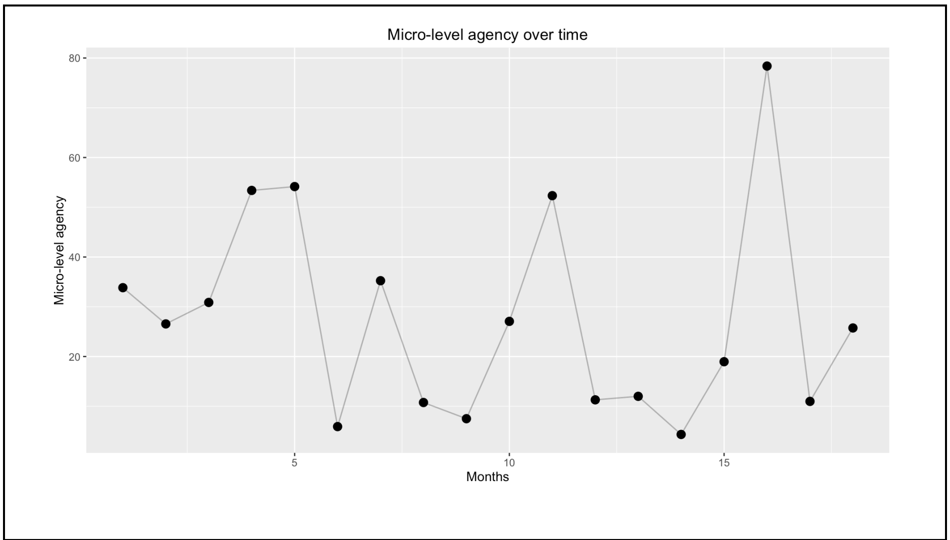


Figure 22. Micro-level agency level over time

In order to identify occurrence of individual micro-shift manifestations and their characteristics, the corresponding micro-shift level for each latent semantic dimension over time was visualised. The resulting heat map in figure 22 reveals 2,016 manifestations of potentially transformative concepts of which 1,194 have positive values indicating the occurrence of at least one concept closely related to a micro-level action (names of each digital agency concept are deliberately unreadable, as they would potentially disclose the identities of specific groups and individuals).

As the heat map in figure 23 reveals, the micro-level agency manifestations appear to be evenly distributed across the semantic dimensions with no dominant sequence dimensional pattern. It does, however, reveal that some conceptual dimensions display higher agency levels at specific points in the case history. This indicates that the emergence of each organisational transformation is affected through a configuration of different types micro-level agency dynamics.

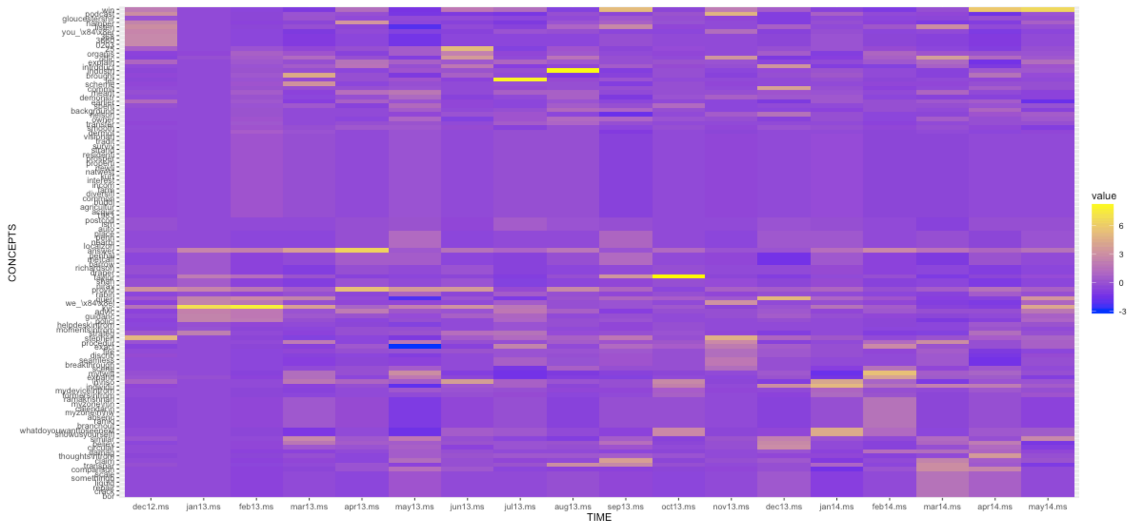


Figure 23. Manifestations of micro-level actions

In order to distinguish specific agency dynamics in the data, I needed to identify groups of semantically related concepts in the data. The initial grouping was computed using unsupervised k-means clustering of the semantic concept space generated in the latent semantic analysis. This initial dissection of agency dynamics revealed five distinct semantic clusters representing separate types of micro-level agency.

The resulting agency types were then cross-validated with themes emerging from the coding of the qualitative interview and document analysis to provide depth of understanding and detailed descriptions of each cluster. This way the computational coding was compared with the original open coding of the interview, document and observational studies. As coding was added to each of the categories, thick descriptions of each agency dynamics were generated. Table 11 shows how the five digital agency dynamics relate to the technological, knowledge and organisational dimensions of the distributed innovation process and describes the characteristics and impact of each type.

Table 11. Typology of Agency Dynamics

Dimension	Description	Type	Impact
Technology	Emergence of technological outcomes through controversies relating to technical deficiencies and suboptimal existing infrastructures	Sub-optimality corrections	Affects device and/or infrastructure level of technological architecture
Knowledge	Changes to the conceptual framework and aspirations of actors as a result of new digital technology	Routine disruption	Disruptions to institutionalised routines as a result of digital technology
		Aspirational refocusing	Changes to aspirations and visions of single actor, or an actor group representing a new cognitive frame for their work
Control	Transformations of institutionalised organisational structures as a result of emerging digital technology	Governance translation	Changes to strategy and policies at various levels of the organisation
		Organisational restructuring	Reorganisation of organisational structures due to introduction of new technological services
Void	Shifts that are based on insufficient external pressures, personal preferences of actors etc. with little or no impact on the digital trajectory	Micro-level actions with one or more components missing	Little or no impact

Using this typology, I was able to plot micro-level agency scores for each type over time revealing the specific agency configuration related to each organisational transformation. The graph in figure 24 illustrates how micro-level agency scores for each type fluctuate with peaks of specific types combining to generate each organisational transformation. This provides a detailed overview of how each trajectory-shaping episode is generated through a unique combination of digital agency dynamics.

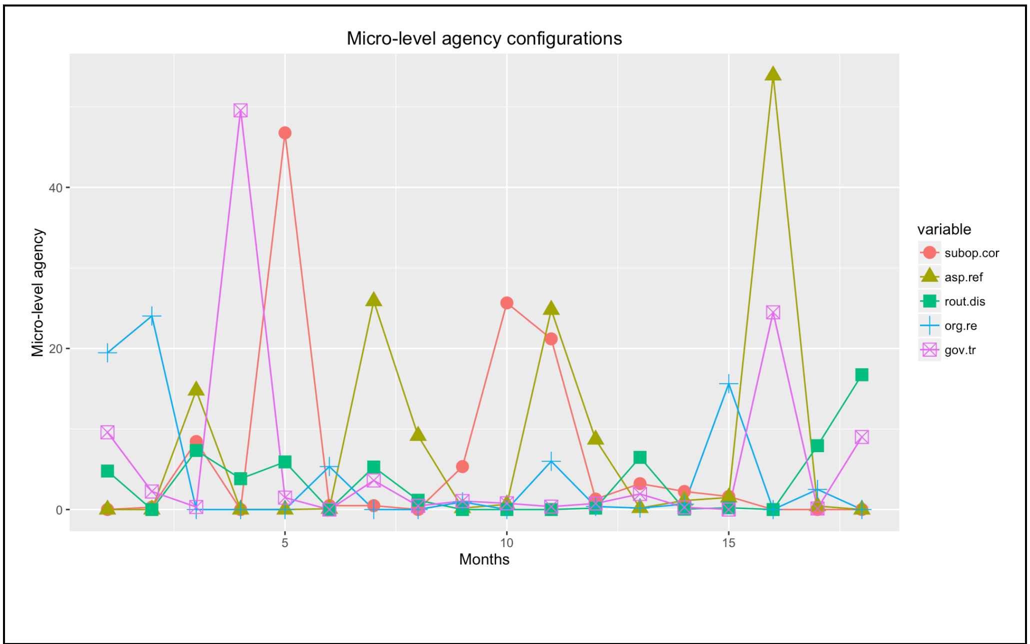


Figure 24. Micro-level agency configurations

The graph in figure 24 can be thought of as the actualised agency configurations at time *t* that can be represented as a 3D space along dimensions of technology, knowledge, and organisational control. When comparing the emergence of organisational transformations with the graph in figure 22 and the innovation network analysis, at least three patterns relating to the trajectory-shaping dynamics of micro-shifts emerge.

First, the natures of the innovation network clusters in which micro-level actions are initiated have an effect on the possible agency configurations and thereby generation of further organisational transformations. Second, a combination of several micro-level action types is needed to affect organisational outcomes.

Third, the prominence of an innovation network context in terms of actors involved surprisingly plays a minor role in its ability to affect organisational transformations. Finally, the sequence of micro-level agency dynamics shows how the accumulation of different agency dynamics combine to produce ever more radical transformations.

5.4 Summary of Findings

In analysing the transformation of frontline customer service in the retail banking network at Barclays, several findings point to the distributed characteristics of the innovation process.

First, the analysis finds that the radical organisational transformation of retail banking emerged through five transformational episodes; the introduction of a new layered modular architecture; the distribution of 8,500 mobile devices within the branch network; the introduction of a new governance structure for mobile work; the rise of a digitally enabled collaborative social conscience; and the reorganisation of the branch network.

The analysis established how each of the organisational transformations emerged from a distributed innovation networks comprising of significantly heterogeneous actor types including individuals, technologies, groups and geographical areas. The network analysis revealed how, over the sequence of organisational transformations, the innovation network was increasingly distributed into micro-level innovation network clusters as more and more actors were mobilised. This indicated that the mobilisation of increasing numbers of actors through process of digital transformation at Barclays did not lead to convergence and centralisation of the innovation network, but rather permeated into new diverging micro-level networks. In summary, the network analysis found that as the process of organisational transformation progressed, it was related to increasing distribution of the innovation network.

Transformations at the organisational level emerged through multiple micro-level events that all included elements of proposition, opposition, controversy and synthesis. The initial qualitative analysis identified 14 such events relating to the five episodes of transformation. These events of micro-level agency were identified as critical from the perspective of human actors central to the process. However, interrogation of digital trace records of interactions related to BankApp revealed 1,194 concepts related to micro-level actions in the 1,843 interactions, indicating the occurrence of a significantly higher number of distributed micro-level actions throughout the case history.

Applying k-means clustering to the concepts relating to micro-level actions provided a typology of five agency dynamics of distributed digital innovation; sub-optimality correction, aspirational refocusing, governance translation and organisational restructuring. Measuring the manifestation of each of the five agency dynamics over time showed how organisational transformations coincide with spikes in specific configurations of micro-level agency.

Having analysed the case of radical transformation of frontline customer service in the retail banking network at Barclays, I now move on to discuss these analytical findings in order to build a theory of distributed agency dynamics in distributed digital innovation.

6. DISCUSSION AND THEORY BUILDING

This chapter discusses the analytical findings presented in the previous chapter with the purpose of building a theory of agency dynamics in distributed digital innovation. The emerging substantive theory is then synthesised to a tentative formal theory, and the possibilities of applying the theory in other empirical contexts are discussed.

The objective of this thesis is to develop a theory of agency dynamics in distributed digital innovation. The tentative theory presented in this section aims to achieve this objective. The theory first combines the various concepts identified in the theoretical review and empirical analyses into a substantive explanation of distributed agency in the case of Barclays. The substantive theory is then integrated with existing innovation theory to provide a tentative formal explanation of how digital trajectories are continuously created through accumulation of multiple distributed actions. By presenting a vocabulary and explanation for distributed agency, the generated theory addresses each of the research questions.

The theory is built in three steps. First, it presents a description of the emergence of organisational transformations through distributed digital innovation at Barclays. The purpose of this description is to explicate how organisational transformations result from multiple agency configurations. It then moves on to discuss the way in which organisational transformations are affected through different structural configurations of the innovation network. Finally, a possible explanation of how specific agency dynamics accumulate into certain shifts at the organisational level is presented.

6.1 Conceptualising Organisational Transformation

This section aims to explain the transformation of frontline customer service at Barclays. In doing so it addresses the research question: What are the characteristics of processes of organisational transformation through distributed digital innovation?

6.1.1 The Manifestation of Digital Transformations

We have seen that organisational transformations are precipitated by specific configurations of digital agency dynamics emerge as a result of accumulation of specific patterns of action in distributed contexts. As a result, the explanation of distributed digital innovation as a centralised act of genius is not applicable to this study. Existing theory has pointed out that: *"…it is important to recognize the danger of this identification of invention with an act of genius."* (Usher 1955, p. 525). Rather, distributed digital innovation should be viewed as an emergent and distributed process in which multiple distributed actions combine into radical transformations (Ruttan 1954; Usher 1955). But if the narrative of the genius entrepreneur is to be abandoned, what then are the powers that generate radical transformations of technological, cognitive and control structures? This question can be explored through a closer empirical investigation of the manifestation of agency configurations at Barclays.

To evaluate and compare the relation between organisational transformations and agency dynamics, I first normalised the digital agency level scores associated with each organisational transformation as shown in figure 24. Measuring the manifestation of each agency dynamic for specific periods of transformation means that the manifestation of specific agency dynamics can be linked to the occurrence of each organisational transformation. The figure shows the digital agency configurations for each period of organisational transformation. Reviewing figure 24 and the plot in figure 22, I can now begin to explain the dynamics behind the actualisation of each organisational transformation.

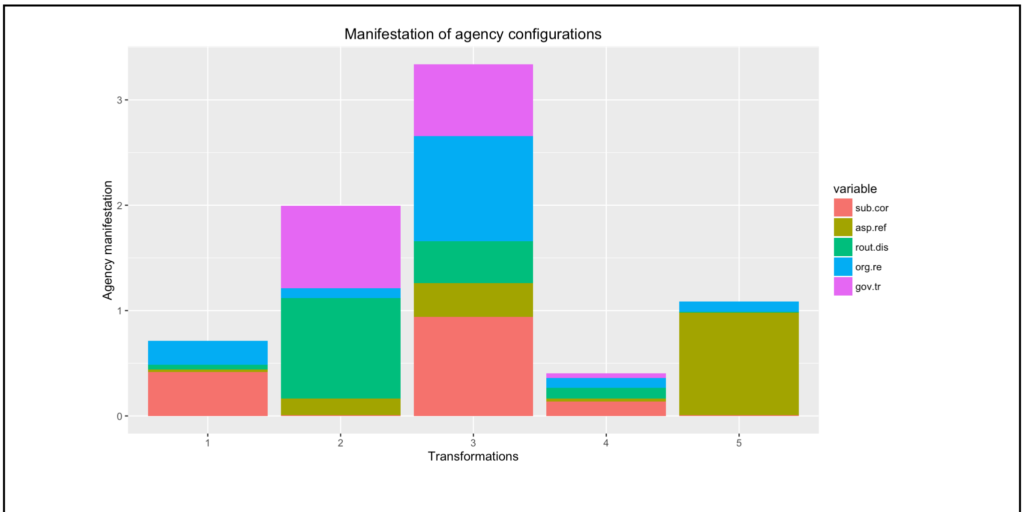


Figure 25. Manifestation of agency configurations

The first organisational transformation representing the development of a new layered modular IT architecture is primarily generated through sub-optimality correction and organisational restructuring actions. The reason for this distribute, and the low scores in general, for this transformation can be found in the fact that the project team and online work group at the time had only just been launched and that the initial interactions were focused primarily on technical development and organising around the new task. In addition, to the users taking part in the work group, the salience of a new infrastructure would be in which ways it would change development and knowledge management routines, which explains the occurrence of routine disruption dynamics.

The second organisational transformation relating to the distribution of 8,500 tablet computers and enforcement of a new role of branch staff was primarily generated through accumulating routine disruption and governance translation dynamics. This indicates the way in which the introduction of mobile devices and a new role for branch staff clashed with existing routines and governance structures. The lack of direct impact on any of the dimensions of digital innovation can be explained through the nature of the qualities of this transformation. Both propositions introduced in the course of this episode met resistance from a number of actors. However, the controversy between incumbent routines and governance structures and introduces technological and organisational propositions had not yet synthesised into a stable outcome.

The third organisational transformation relating to the introduction of the support network and BYOD policies and establishing of a digital support network is primarily actualised through a mix of sub-optimality correction, governance translation and organisational restructuring dynamics. This configuration shows strong manifestations of a broad spectrum of digital agency dynamics, all showing high agency levels, indicating a significant organisational transformation where multiple dynamics converged to affect several dimensions. As the relatively high sub-optimality correction score can be explained by the proliferation of existing technology to more users, the main outcomes are related to impact on the knowledge and organisational control dimensions.

The fourth organisational transformation relating to the emergence of a new 'collective conscience' in the wake of the release of BankApp version 2 shows relatively low and insignificant digital agency levels for all but the sub-optimality disruption and routine disruption dynamics. This indicates a relatively low impact to the knowledge resource dimension, affected by new digital technology and as a consequence changes to knowledge practices.

The final organisational transformation actualised around the restructuring of the branch network shows high levels for the aspirational refocusing dynamic with some manifestation of organisational restructuring. This indicates that this organisational transformation was focused primarily on the strategical implications and new visions arising in the wake of the digitalisation of the frontline customer service. Therefore, impact was primarily to the organisational dimension and did not generate outcomes in the technological or knowledge resource dimensions.

This explanation reveals a pattern in the sequence of impacted dimensions, where the initial two transformations involved changes to technological dimensions, the following two changes to the knowledge resource dimension and the final transformation involved change to organisational dimension. This pattern of technological change leading to changes in knowledge structures that in turn enable organisational change, can be explicated by examining the accumulation of transformational dynamics over time. The cumulative sequence of innovation outcomes can be expressed as shown in table 13, where T represents technological, K represents knowledge, O organisational and Ø void or unsuccessful impact.

Table 13. Sequence of Organisational Transformations		
Transformations	**Agency dynamics**	**Accumulated organisational transformations**
Transformation 1	Routine disruption	T1 -> T2
Transformation 2	Aspirational refocusing	T2 -> Ø
Transformation 3	Sub-optimality correction Governance translation Routine disruption	T1 + T2 -> K1
Transformation 4	Routine disruption	T1 + T2 + K1 + -> K2
Transformation 5	Organisational restructuring	T1 + T2 + K1 + K2 -> O

As table 13 suggests, a key proposition about the shaping of radical transformations through distributed digital innovation pertains to the general sequence of organisational transformations. It suggests that trajectories of radical digital transformation are contingent upon a pattern of accumulating transformations starting with technological, then knowledge related and finally organisational transformations. As illustrated in the right most column of table 13, the sequence of organisational transformations in the radical transformation of the branch network at Barclays can, using the annotation described above, be represented as:

`T1 -> T2 -> Ø -> K1 -> K2 -> O`

This suggests a sequence or path of distributed digital transformation through which changes in technological structures require knowledge related transformations that then combine into more radical transformations at the organisational level.

While this pattern explains the sequence of digital transformation, it does not account for the structure of the innovation network and how it constrains and enables this transformation. The next section first discusses the nature of actors involved in digital innovation network before detailing the relation between the structure of innovation networks and the process of transformation at the organisational level.

6.2 Conceptualising Innovation Networks

Distributed digital innovation changes the locus of explanation from a small number of high magnitude actions by a relatively small group of individuals to a myriad of small magnitude actions performed at multiple distributed yet interconnected local contexts (Usher 1955). This section addresses the research question relating to the distributed structure of digital innovation networks and how they lead to organisational transformation by reviewing the characteristics of different actor types and how the structural characteristics of their interconnections relate to organisational transformation.

6.2.1 Actors, Algorithms and Actants

The innovation network analysis presented in section 5.2 identifies multiple different types of actors in the data including human individuals, technologies, geographies, and topics. In order to theorise these findings, it is necessary to dive deeper into the specific dynamics of digitally enabled innovation activity. The empirical analysis in this thesis suggests that the characteristics and affordances of digital technology enable the emergence of ideas, topics, groups and geographies as actants in the innovation network by allowing humans to assume any number of actant positions, including those of topics and geographies.

Based on this analytical finding and reference theory of this research, specifically that of digital innovation (e.g. Boland et al. 2007; Boudreau 2012; Yoo et al. 2008) and sociotechnical networks (e.g. Latour 1991a; Venturini 2009, 2012), I propose the following three types of actors play a role in distributed digital innovation: 1) digitally distributed human agents, 2) algorithmic agents and 3) digitally emergent actants. The following sections discuss the characteristics of each of these three types of digital actors in turn to build an understanding of the distributed actants that affect digital transformations.

Digitally Distributed Human Agents

In the context of distributed digital innovation, actors create new paths by challenging *"...how boundaries and relations are enacted in recurrent activities"* (Orlikowski and Scott 2008, p. 462). These interactions are traditionally represented as a network of human actors connected by trajectory shaping activities. While some research focuses exclusively on the structural properties of innovation networks (Gloor et al. 2008; Peng and Mu 2011), largely ignoring the reflexivity and agency of individual actors, other researchers have focused specifically on the importance of individual actors and left out structural accounts (Swan et al. 1999). Yoo et al. (2008) identify four types of innovation networks based on the distribution of coordination and control, and heterogeneity of knowledge resources. They suggest that through the distribution of both coordination and control and access to knowledge resources that occurs when previously unconnected actors are brought together through digital technology, digital innovation networks in this sense become 'doubly distributed' (Yoo et al. 2008, p. 5).

Human actors are distributed across three dimensions. Including the distributed characteristics of digital artefacts themselves, this involves a triple distribution of access to artefacts, diversification of knowledge resources and distribution of control structures (see section 2.1 for more detail on each dimension). Consequently, control of and access to innovation is distributed from a centralised group of entrepreneurs to the periphery of the organisation. Recent literature on distributed innovation networks shows how heterogeneity of knowledge resources and distribution of control has led to new forms of digital innovation (Dhanarag and Parkhe 2006; Yoo et al. 2008) with strategic consequences for the management of innovation processes where orchestration of collaboration and interactions in innovation networks replaces command and control (Dhanarag and Parkhe 2006; Zachariadis et al. 2013).

Such distribution materialises in one of three levels: 1) the level of the team as an organisational entity with a specific predefined goal (Gaan 2012), 2) the level of subgroups and inter-subgroup dynamics effect on team outcome (Carton and Cummings 2012; Suh et al. 2011), and 3) on the level of the structural relations between individual within and between distributed contexts (Balkundi and Harrison 2006; Sarker, Sarker, et al. 2011).

Existing research on distributed collaboration has focused on analysing the effect of different variables on performance on the level of distributed groups or clusters within an organisation. Explanations represent a wide span of accounts of around how effective digitally distributed groups are at completing tasks that were formulated a priori to group formation within the boundaries of pre-existing organisations (Badrinarayanan et al. 2011; Berry 2011; Gaan 2012), determined by variables such as composition and group size (Alnuaimi et al. 2010), skills and knowledge of team members (Berry 2011), and technology (Gaan 2012). Other literature explores the coordination of knowledge over geographical, temporal, and social boundaries as an advantage of digitally distributed groups in working more effectively (Bell and Zaheer 2007; Kanawattanachai and Yoo 2007; Ratcheva 2008), while others yet have focused on trust (Jarvenpaa et al. 1998) and social capital (Robert et al. 2008) as drivers for organisational performance.

However, digitally distributed actors are not necessarily confined to a single organisation. Recent theoretical developments suggest that a deeper understanding of distributed digital contexts beyond focusing on localised groups as a part of a larger, pre-existing organisation (Sarker et al. 2011). Digitally distributed groups are to a large extent are formed, or emerge, for ad hoc interactions and problem solving (Gaan 2012). One study of massive multi-player online gaming communities found that participants increasingly self-organize in localised groups around highly complex tasks (Mysirlaki and Paraskeva 2012). These emergent and digitally distributed groups emerge along a three-dimensional scale on the axes of temporal stability (enabled by e.g. technology), knowledge differentiation (e.g. shared cognitive schema among actors) and authority differentiation (embedded in control structures) (Hollenbeck et al. 2012).

As illustrated in the case of digital transformation of retail banking at Barclays, distributed collaboration contexts increasingly involve interactions with non-humans in the form of algorithms and automated digital agents, an exclusive focus on localised organisation and agency of human actors is no longer sufficient to describe the agency exerted in digitally enabled settings.

Digital Agents

Recently emerging IS literature conceptualises how a new digital agents are capable of decision-making and interaction by feeding off an increasing amount of digital traces (Newell and Marabelli 2015; Orlikowski and Scott 2013).

Previous notions of technological agency in actor network theory have been criticised for over extending the limited 'causal agency' built into the mechanics of any machine (Bloor 1999). While technical definitions of algorithms range from sequential operations, parallel processing and distributed operations including calculation, data processing, and automated reasoning (Aho and Hopcroft 1974; Blass and Gurevich 2003), a new breed of algorithms in the shape of e.g. neural networks (Eletter et al. 2010), genetic algorithms (Goldberg and Holland 1988) and deep learning (Marsland 2014) are radically reshaping digital trajectories by performing complex operations on digital traces.

In order to trace the agentic characteristics of such digital agents, I draw definitions from actor network theory arguing that in order to exhibit agency, any human or nonhuman actor needs simply to affect an observable change in the course of some other agent's action (Latour 2005, p. 71) with no absolute or final division made between the capacity of humans and nonhumans to exercise agency (Callon and Latour 1992). For example, an online loan application decisions made by digital agents at wonga.com operate through collating a large number of interactions individual human beings (e.g. employment and personal spending decisions), assessments made by other algorithmic agents (e.g. credit score calculations), and then processing all of these decisions using the internal structure of Wonga.com's own algorithms, which in turn are influenced by their own past decisions, i.e. to determine the relationships between credit scores and interests rates which maximise the chance of profitable transactions.

A digital agent is defined as a digital assembly that, based on a wide range of possible states and learning from its own decision history, affects the actions of other agents. This means that it must possess a) some form of intelligence by way of being open to receive input from its environment and translate it to the form of binary data b) some level of machine learning (Marsland 2014), which processes present input based on its own decision history (Goldberg and Holland 1988), and c) the ability to affect observable change to the actions of at least one other actor by interpreting binary data and presenting it in a form that is comprehensible to human agents.

As an ingrained part of our daily experiences, we routinely interact with digital agents such as Apple's Siri, Google Now and Search and Amazon's recommendation engines when we 'ask Google' or buy a book 'suggested by Amazon '. In addition, we routinely accept the agency of numerous digital agents employed by companies and government. Yet, existing theoretical perspectives on technological agency offer little guidance in the effort to explore the intelligence, learning capabilities or agentic effects of digital agents (Yoo 2010).

In the case of Barclays, digital agents primarily played the role of community maintenance as they served use statistics and updates about new users and topics being added to the online work group. As such, interactions from digital agents were frequently commented, but any elicitation of feedback in these comments was primarily directed at other human actors. As such, even though digital agents were identifiable in the data, they did not play a significant role in the transformation process.

Digitally Emergent Actants

The agentic properties of digital agents described above (i.e. intelligence, learning and decision making) are not confined exclusively to human or digital actors. The definition of agency as the ability to affect change in the course of action of other actants means that agency can also emerge as characteristics of distributed innovation networks. In the Barclays case study, this is seen in the prevalence of technologies, topical and organisational groups, and geographical areas as actants in the innovation network.

This phenomenon can be explained through the prevalence of action over actors in innovation networks as conceptualised in recent developments in ANT (Czarniawska 2004; Garud et al. 2010; Pentland and Feldman 2007). Consequently, the cast of actors within a specific innovation network context is contingent upon the required actions to be enacted rather than on a static list of existing actors. That means that the actors of actor network theory are more accurately described as semiotic actants or actant positions, i.e. as roles in a system to be filled rather than as ontological actors. In other words, each context requires a set of roles to be filled, and actants will take the required roles to actualise the agendas of the micro-level innovation network.

Interestingly, some actant positions such as e.g. groups, topics and geographies emerge as actant positions on par with human and digital actors. Human or digital actors assuming the communicative position of for example an entire group or geographical location fill these actant positions. This is manifested in the digital trace records as interactions between individual actors and e.g. groups, topics and geographies.

On social media, the use of hash tags means that actors routinely direct questions at topics, professions, interest groups and even geographies. I propose that this same dynamic that is an intricate part of social media discourse is also present in the context of distributed digital innovation. Furthermore, I suggest that these emergent digital actants can participate in the distributed actions of digital innovation by filling the role of initiator, opponent and/or by taking part in the unfolding micro-level controversies that generate localised innovation outcomes.

Having discussed the role of the actant types that emerged from the case analysis, I now move on to discuss the relation between the structure of the innovation network and specific organisational transformations.

6.2.2 Innovation Network Structure and Organisational Transformation

In order to draw the connection between innovation network structure and organisational transformations, I computed the modularity and clustering coefficient of the innovation network during the specific periods that corresponded with the emergence of each organisational transformation as shown in table 14. This provided specific measures for computational identification of the range and structure of micro-level network clusters associated with each transformation.

Table 14. Innovation Network Metrics					
	Trans. 1	**Trans. 2**	**Trans. 3**	**Trans. 4**	**Trans. 5**
Actors	35	345	212	228	423
Actions	36	654	387	338	920
Density	0.030	0.006	0.009	0.007	0.010
Avg. degree	1.029	1.896	1.825	1.482	2.175
Diameter	2	7	3	3	4
Clustering coefficient	0.000	0.059	0.070	0.044	0.058
Modularity	0.532	0.461	0.594	0.624	0.385
No. clusters	7	14	12	21	29

Table 14 shows how the initial organisational transformation (T1) resulting in a new, layered IT architecture involved a small number of actors distributed in a relatively high number of locales. The introduction of bank sponsored tablet computers represented in the second transformation (T2) mobilised a high number of actors across 14 locales, but failed to produce a coherent organisational transformation as illustrated by the low-density measurements for the corresponding innovation network meaning that interaction between clusters was limited. In contrast, the new governance structure emerging in the third transformation (T3) shows high modularity and clustering coefficient indicating the coordination of different locales across the organisation. The fourth episode of transformation (T4) represents the distribution of knowledge production and consumption across the organisation as illustrated by the relatively high modularity and low network density indicating specialization into more autonomous locales. Finally, the restructuring of the branch network represented in the fifth episone of organisational transformation (T5) mobilised a high number of actors in an increasingly distributed network engaging heavily with each other as indicated by the high average degree of 2.175 interactions per actor.

This finding reveals at least two interesting insights into the relation between innovation network structure and affected organisational transformations. First, the ability of micro-level actions to accumulate into localised controversies and organisational transformations is not sufficiently explained by the mere actualisation of high volumes of micro-level actions. The analysis suggests that the way in which such actions are structured in relation to other micro-level actions plays a significant role in explaining their transformational capacity. Following from this, the capacity of innovation network structure to invoke transformational powers is not a simple correlation with the number of links, or density, found in the innovation network, but in how the innovation network structure adapts to the specific qualities and characteristics of each organisational transformation. This suggests that the capacity of the innovation network to evolve and adapt to specific contexts rather than its capacity for link building, is the key factor in facilitating radical transformations. Following from this, the question of how transformations diffuse through the innovation network is left open.

6.2.3 Diffusion of Organisational Transformations

As the success of organisational transformations depend primarily on network adaptability and link structure is therefore not a good indicator of diffusion, this section will discuss the possible ways in which innovations diffuse based on the findings of this thesis.

The finding that adaptation of distributed innovation network contexts is the main driver of organisational transformation suggests that organisational transformations do not diffuse in the sense of being transmitted across the network. Rather, the findings of this research suggest that organisational transformations *emerge* from multiple distributed interactions in the form of controversies. This means that transformations travel through the innovation network in a chain of adaptations based on multiple localised controversies and syntheses. As discussed in previous chapters and illustrated in the analysis, micro-level interactions include a proposition, opposition from at least one other actor and a negotiation of a local synthesis. The analysis shows how a synthesis produced in one innovation network context has the potential to act as a proposition in other network clusters. This finding shows that transformations do not diffuse directly through the innovation network, but are the effects of multiple local synthesis on adjourning network contexts. The diffusion thus takes place as local adaptation rather than global transmission. Figure 26 illustrates how transformations diffuse through the innovation network through a series of localised interactions and syntheses.

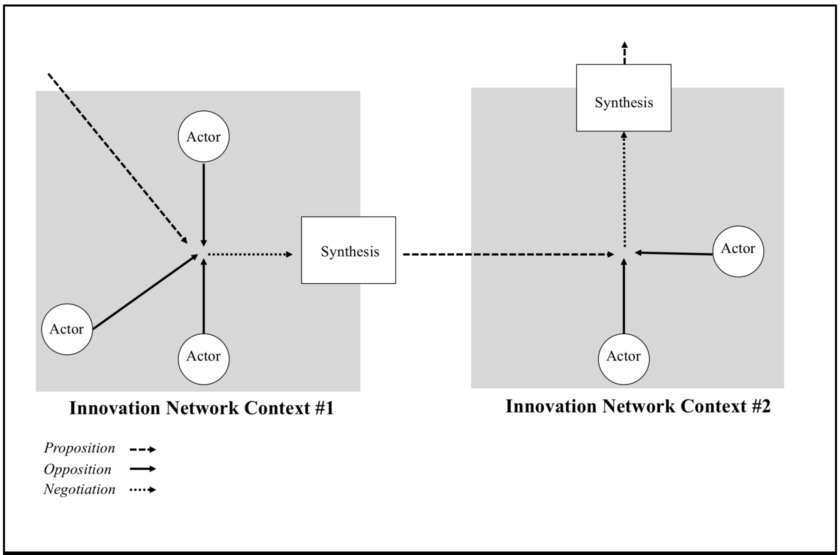


Figure 26. Micro-level diffusion of organisational transformation

It is outside the scope of the analysis included in this thesis to explain the details of exactly how localised adaptations travel through the innovation network. However, based on the findings presented above and in figure 26, I propose the following patterns of adaptations can be found should more detailed analysis be conducted:

1) *Adaptation*: A similar innovation network context adapts a proposition from innovation network context 1 to its own context. The proposition in this case adapts the existing operation of innovation network context 2 thus changing the scope and speed of operation in context 2 while retaining its functional qualities.
2) *Perturbation*: A synthesis generated in innovation network context 1 draws such significant opposition in that the operation of innovation network context 2 changes significantly.
3) *Resistance*: The proposition is overwhelmingly opposed and no synthesis is negotiated. This leads to a reinforcement of the existing operational patterns of context 2 while the effect of the synthesis from context 1 on organisational transformation changes.

All three patterns in different ways affect organisational transformation as they contribute to the agency dynamics that emerge into organisational transformations. Further research efforts are needed to refine and explain this micro-level dynamics. Especially more detailed analysis of the exact ways in which some micro-level synthesis disperses and, in non-linear fashion, affect the emergence of organisational transformations. Next, I move on to discuss how such distributed adaptations in the innovation network affect emergent organisational transformations. Specifically, the following sections discuss the specific characteristics and dynamics of the multiple distributed actions that interact to produce organisational transformations.

6.3 Conceptualising Distributed Agency Dynamics

This section addresses the research question relating to the characteristics and dynamics of distributed actions that affect radical organisational transformation. This is achieved by discussing the characteristics and dynamics of distributed actions that enable them to effect organisational transformations. First, the accumulation of micro-level actions is conceptualised before moving on to discuss the transformative power of specific agency dynamics.

6.3.1 Accumulation of Micro-Level Actions

As demonstrated in the analysis in section 5.3, organisational transformations emerge as a result of accumulation of specific configurations of digital agency dynamics. Each type of agency dynamics is manifested through multiple distributed micro-level actions, including propositional and oppositional actions, resulting in an outcome that are specifically adapted to each micro-level innovation network cluster. Together, such micro-level actions constitute a controversy resulting in the adaptation of new propositions to the specific distributed context with the potential to affect transformation at the organisational level. A distributed network of digital actants including human actors, digital agents, and digitally emergent actants enacts each such path creating controversy.

An example of this process of accumulation and emergence in the empirical analysis can be found in the first organisational transformation relating to the emergence of a layered IT infrastructure. As the initial proposition from the design team for a mobile app was opposed by the IT security team, it resonated with other micro-level actions associated with fundamentally different agency dynamics related to information access and customer service strategy. This accumulation of controversies involving different agency dynamics combined to affect a synthesised solution resolving multiple connected micro-level controversies thus resulting in an organisational transformation in the technological dimension. The innovation of a new layered IT architecture at Barclays can therefore not be ascribed to a single actant or group of entrepreneurs, but must be seen as a configuration of colliding and accumulating agency dynamics cascading across multiple distributed contexts.

While each micro-level controversy seems insignificant in isolation, the co-occurrence and combination of multiple controversies means that together they have the potential to accumulate into powerful configurations that affect radical organisational transformations of technology, knowledge resources and organisational control structures.

A key element in assessing the potential of such accumulating micro-level actions to affect organisational transformation, is that of the transformational power of specific agency dynamics and agency configurations to lead to organisation-level outcomes. These potential powers of agency dynamics are discussed in the following section.

6.3.2 The Transformative Power of Agency Dynamics

Based on the empirical analyses and theoretical investigations presented throughout the thesis, this section explores how organisational transformations at Barclays were affected by different agency dynamics. This discussion provides the second step in addressing the research question pertaining to the characteristics and dynamics of micro-level actions that shape digital trajectories. Having measured the configurations of digital agency dynamics for each organisational transformation in figure 23, allows me to estimate the impact of each agency dynamics in terms of its capabilities to generate transformations in one of the three dimensions of digital innovation. Calculating the relative impact of each digital agency dynamics on each digital innovation dimension produced such estimation as shown in table 15.

In order to provide a better understanding of the dynamics by which agency configurations emerge into organisational transformations I now discuss the specific conditions and dynamics of digital agency configurations at Barclays in greater detail.

Having measured the configurations of digital agency dynamics for each organisational transformation in figure 23, allows for an estimate of the relative impact of each agency dynamics in terms of its capabilities to generate transformations in one of the three dimensions of digital innovation. Such as estimation is shown in table 15.

Table 15. Impact of Digital Agency Dynamics

Normalised agency score by dimension

Digital agency dynamics	Technological dimension	Knowledge dimension	Organisational dimension
Sub-optimality correction	0.78	0.04	0.16
Aspirational refocusing	0.04	0.37	0.06
Routine disruption	0.06	0.38	0.04
Organisational restructuring	0.10	0.13	0.49
Governance translation	0.02	0.01	0.25

Table 15 indicates that the technological dimension is primarily affected through sub-optimality correction dynamics. The knowledge dimension is affected through a mix of routine disruption and aspirational refocusing dynamics with a secondary impact affected through the organisational restructuring dynamics. Finally, the organisational control dimension is primarily affected by organisational restructuring and governance translation dynamics, with a secondary impact from sub-optimality correction dynamics. Interestingly, sub-optimality correction seems to play a role in organisational transformation suggesting that the sub-optimalities are experienced in both technological and organisational systems.

This result seems to validate the identification of agency dynamics, as each agency dynamic seem to influence transformations in dimensions representing relevant topics. This means that, within certain boundaries, the transformation of each dimension of distributed digital innovation is connected to a specific configuration of distributed agency dynamics.

In summary, the distributed process of innovation represented in this research is contingent upon three main factors. They are: 1) the sequence of previous transformations, 2) the evolution of innovation network composition over time, and 3) the configuration of agency dynamics enacted in the innovation network.

This indicates that two opposing forces are at play in the distributed digital innovation of frontline service at Barclays. One is the generative force of accumulating agency dynamics breaking with existing trajectory and endangering incumbent technological, knowledge related and organisational structures, while the other is the constraining power of the history of previous organisational transformations and innovation network structures stabilising new technology, knowledge resources and organisational structures.

While these findings serve to address the theoretical contribution target of this thesis by explaining distributed agency in digital innovation at Barclays, the substantive nature of this theorising leads to the question of how to build a more generalizable and formal theory. The next section addresses this question by integrating the substantive conceptualisation with existing theory to propose a tentative theory of the agency dynamics of distributed digital innovation.

6.3 Explaining the Agency Dynamics of Distributed Digital Innovation

The theory of the agency dynamics of distributed digital innovation that is put forward in this thesis describes and explains processes of innovation that occur as distributed and emergent digitalisation. It proposes that the agency dynamics related to these processes are comprised by multiple micro-level actions accumulating into distributed controversies whose outcomes manifest through one of five agency dynamics. These agency dynamics in turn accumulate into powerful agency configurations with the potential to affect radical organisational transformation.

6.3.1 Distributed Digital Innovation as Cumulative Synthesis

From the Gutenberg's printing press to Steve Jobs' iPod, stories of great innovations emphasising the vision and industry of a single entrepreneur are abundant and deeply ingrained in our thinking about technological change. This seems to be especially true when it comes to digital innovation, where entrepreneurs like Bill Gates and Steve Jobs have become legends in their own right shrouded in myths and idolisation.

However, closer analytical scrutiny will reveal that the emergence of the printing press was delayed by about two centuries from its invention, why the radical transformations in its wake cannot exclusively be ascribed to Gutenberg (Ong 1978). Similarly, radical transformations in modern industries associated with more recent information systems such as the iPod did not emerge as a result of some stroke of genius by a single entrepreneur, but were conditioned by the standardisation of digital audio formats and the mobilisation of global innovation networks consisting of peer-to-peer technologies, consumers and musicians as well as the institutional structure and history of the music industry.

Following from the findings presented in this thesis, it is important to realise the perils of identifying innovation with an act of genius. This leads to a narrative that over-emphasises a relatively small number of actions, which are each of them highly conditional as described previously in this section. A second danger of adopting a narrative of innovation centred around a single protagonist entrepreneur is to view the continuous process of innovation as punctuated and infrequent events of great magnitude (Gersick 1991; Romanelli and Tushman 1994). Instead, the notion of distributed digital innovation provides a narrative of innovation building on changes that *"…are numerous, pervasive, and of very small magnitudes"* (Usher 1955, p. 525).

While various Schumpeterian views of the emergence of innovations have been the prevalent underpinnings of the majority of research on technological trajectories (cf. Breschi et al. 2000; Dosi 1993), there is, as demonstrated in the literature review, nothing in Schumpeter's work to suggest a theory of how trajectories are created through distributed actions (Ruttan 1954). In fact, Schumpeter's theory to a large extent diminishes the role of local agency in favour of focusing on the constraints enacted by macro-level mechanisms on the implementation of new technology. In this sense, a Schumpeterian concept of technological transformation as the result of external constraints seems to be incongruent with the description of the digital transformation of retail banking at Barclays presented in this thesis.

The analysis of distributed digital innovation presented in this thesis conceptualises digital transformation as emerging from the cumulative aggregation of relatively simple actions, each of which requires a micro-level controversy resulting in a small-scale changes in the shape of technological, knowledge related or organisational inventions. This notion of small-scale agency, which relates to the notion of bricolage in path creation discussed in chapter 2 (Garud and Karnøe 2003), is captured more precisely in Abbot Payson Usher's concept of 'cumulative synthesis' (Usher 1955).

Drawing on research based in Gestalt psychology, Usher describes tree types of actions: innate actions, actions of skill and acts of insight. Innate actions are actions any individual can perform such as walk, breathe, eat etc. Acts of skill refers to actions that are learned, either through experience or through instruction from other individuals. These first two types of action are therefore not prevalent in the initiation innovation, but play a vital role in conditioning acts of insight, which refers to acts of unlearning, extending and recombining such previous knowledge. Cumulative synthesis is a process beginning with the realisation of a sub-optimal pattern, then a ‘setting of stage’ by proposing new combinations, generation of new insight through the combined input of multiple local actors and finally the critical revision and development of synthesised local adaptations.

The analytical findings of this research propose that controversy plays a key role in the manifestation of acts of insight by challenging existing knowledge structures and producing emerging syntheses that deviate from existing trajectories. The process of cumulative synthesis from multiple conditioned controversies *“…requires a notion of a sequence of acts of insight which leads to a cumulative synthesis of many items which were originally independent”* (Usher 1955, p. 529). While the notion that trajectory level innovation emerges from a widely distributed heterogeneous actions has recently regained the interest of researchers of socio-technical change (Czarniawska 2004; Geels 2005), the micro-level dynamics generating these outcomes in the context of digitalisation and digital innovation are still under theorised.

The account of a digital transformation of retail banking at Barclays presented in this thesis provides an empirical basis for a conceptualisation of such dynamics. The evidence presented from the Barclays case analysis suggests that the digital transformation of retail banking emerged mainly through multiple micro-level adaptations combining to generate radical outcomes. Rather than a traditional Schumpeterian case, the Barclays account is more consistent with the conceptualisation provided by the theory of cumulative synthesis.

Additionally, the specific characteristics of digital technology means that organisational transformations are likely to emerge from distributed innovation networks. The analysis conducted in this thesis suggests that the distributed accumulation of micro-level actions into organisational transformation is contingent upon at least four conditions: 1) The technological resources and digital infrastructure available, 2) the structure and characteristics of the innovation network in which it occurs 3) the specific constitution of micro-level actions into localised controversies, and 4) the history of previous organisational transformations created through specific agency configurations.

First, the mobilisation of heterogeneous actants in the innovation network depends on the technological resources and infrastructures available to the organisation. This means that at any given time in the shaping of a digital trajectory, the mobilisation of actants, and thereby the perspectives represented in each local context, is contingent upon the architecture and affordances provided by digital infrastructures. This way, the constitution of distributed micro-level innovation networks depends on the ability of the digital infrastructure to include different types of actants throughout the organisation. In the case of Barclays, the initial lack of digital infrastructure beyond email limited the number of actants participating in digital innovation to employees with email, i.e. those working at headquarters and support functions. This meant that the majority of frontline staff were initially excluded from participating in the innovation network as can be seen in the innovation network analysis presented in section 5.2.

Consequently, the constitution and structure of the innovation network plays a key role in instantiating trajectory-shaping controversies. The degree of distribution, number of network clusters and the formation of structural links between distributed clusters influence the ability of micro-level actions to accumulate. Also, the innovation network analysis suggests that the diversity and combination of different types of actants participating in the innovation network plays a role. The effects of the structural properties of the innovation network manifests in the analysis through the differences in syntheses produced by various innovation network clusters during each organisational transformation. The analysis shows how structural properties such as high innovation network density, a measure of interaction between distributed locales, in the case of BankApp positively impacts the innovation network's ability to produce transformational syntheses.

However, the structure of the innovation network is more of a precondition than a determinant of specific transformations. Moreover, the specific composition of accumulated agency dynamics at each period of organisational transformation produces a unique synthesis of micro-level outcomes. This way, the shaping of a digital trajectory depends on the specific agency configuration instantiated at the time of the organisational transformation as seen in the Barclays case study. The analysis shows how different configurations of agency dynamics lead to organisational transformations in different dimensions of digital innovation, i.e. technological, knowledge related and organisational dimensions.

Finally, the actualisation of an organisational transformation depends upon the transformation preceding it as well as the entire sequence of previous organisational transformations. While digital trajectories are historically constrained, they are not causally determined by previous organisational transformations. This can be understood in the way that the past history of a sequence of transformations provides a space of possible micro-level actions that can potentially be instantiated by digital actants. For example, the lack of digital infrastructure initially inhibited some actants from participating in the innovation network and later provided a space of opportunity for numerous new actants to participate, resulting in new agency configurations and ultimately in radical transformations of retail banking at Barclays. This way historical constraints determine a space of possible innovation within which distributed micro-level actions accumulate into emerging syntheses at the organisational level.

While each of these contingencies play a role in the instantiation and accumulation of the agency dynamics that shape digital trajectories, they do not specifically explain how organisational transformations emerge from multiple distributed actions. For this we need a theory that explains the relation between micro-level actions and macro-level transformations. Such a mechanism can be described by explaining the findings of this research based on the notion of cumulative synthesis discussed above. I label this mechanism of agency dynamics in distributed digital innovation 'double-cumulative synthesis'.

6.3.2 The Agency Dynamics of Double-Cumulative Synthesis

In the context of the case of distributed and emergent digital innovation presented in this thesis, cumulative synthesis has occurred at the two distinct levels of micro-level innovation network and organisational transformation. This is to say that the process described as cumulative synthesis above unfolds at these two levels and that the cumulative syntheses produced are connected through agency configurations and innovation network structure. The two distinct levels at which cumulative synthesis occurs relate to local adaptation of new innovations and shaping of organisational transformation respectively. Combining these conceptual elements reveals a mechanism by which radical transformations at the trajectory level emerge from multiple distributed interactions. I will now describe each of the two instances of cumulative synthesis before combining them to, based on the findings in this research, propose a mechanism of agency dynamics in distributed digital innovation.

Synthesis 1: Local adaptation

As actants engage in innovation networks they perform a multitude of locally bounded micro-level actions in the form of innate actions, actions of skill and acts of insight (Usher 1955). Innate actions are inherent operations to do with maintaining their presence in the innovation network such as updating their profile or joining and leaving communities and topical groups. Acts of skill includes both routine based interactions performed by human actors and sequentially programmed mechanical actions such as generating community statistics and auto-generating notifications undertaken by algorithmic agents. Common for acts of skill is that they follow a scripted instruction in the form of either a set routine or digitally coded sequence of step. Acts of insight involves reflecting on the set procedures and unlearning existing routines to adapt the innate and skill related actions performed in the local innovation network context to new external conditions. These acts of insight thus represent the unlearning of old schema and the generation of new syntheses adapted to the localised context.

The accumulation of micro-level actions therefore represents an inherent tension between the re-enactment and unlearning of incumbent skills, routines and processes. This inherent tension results in multiple controversies consisting of micro-level actions representing propositions, opposition and synthesis within the local context. In this way multiple micro-level actions of various types accumulate into local adaptations through path creating controversies, resulting in local adaptations performed by a distributed network of digital actants. However, these distributed micro-level controversies are but isolated instances if not for the fact that they combine to generate organisational transformations. Such accumulation of agency dynamics into organisational change is described as synthesis 2.

Synthesis 2: ***Organisational transformation***

When localised micro-level actions are instantiated, they materialise in a variety of different agency dynamics as described in the previous chapter. At any given time, a large number of distributed micro-level actions representing varying agency dynamics combine into unique configurations, which, conditioned by the innovation network properties described previously, in turn affect organisational change. At this level, it is not micro-level actions that accumulate, but the agency configurations generated through multiple local controversies. In other words, trajectory shaping happens as a synthesis of syntheses representing a second order emergent level of distributed digital innovation (Lu and Ramamurthy 2011).

The outcome of this second order accumulation is potentially radical transformations of technology, knowledge resources and control structures. Each organisational outcome in turn invokes changes to the initial conditions for specific distributed micro-level networks. Transformations at the organisational level invoke micro-level network change and thereby represent a new set of propositions in each micro-level innovation network. Thereby this second order accumulation explains how localised controversies enacted by heterogeneous actants affect organisational-level changes to either the technological, knowledge related or organisational dimensions of digital innovation. Specific digital agency configurations will tend to, under the conditions described in the previous section, affect changes to certain digital innovation dimensions. Specific changes to a given dimension will therefore shape the organisation in a certain direction along an on-going digital trajectory.

Figure 27 shows how each organisational transformation in turn invokes changes to the conditions for the distributed organisation of innovation networks. These conditions include changes to technological capabilities, knowledge practices, and rules and procedures that affects the availability and affordances of the digital infrastructure, the accessibility of the innovation network for certain actant groups, and the distribution and structure of the innovation network itself.

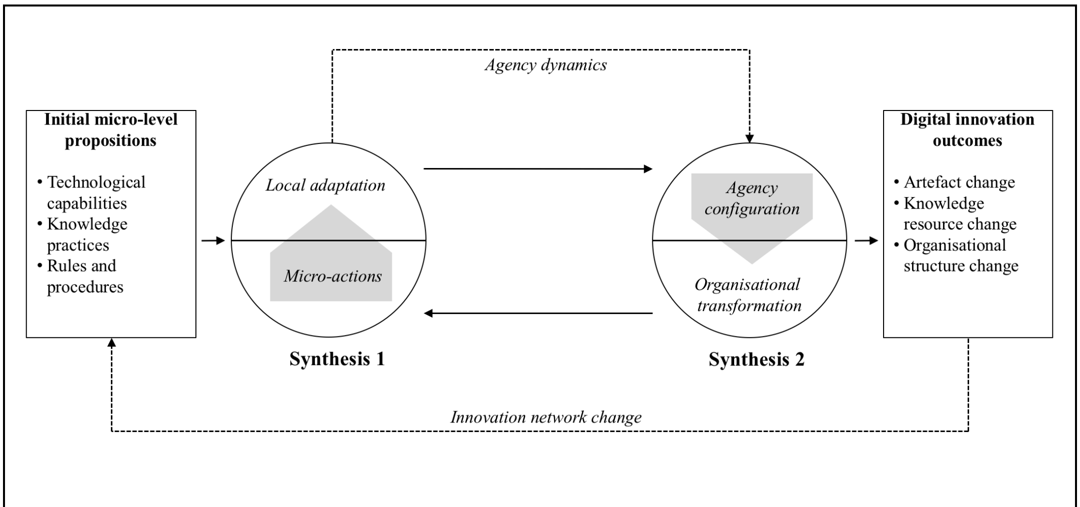


Figure 27. Agency dynamics of double-cumulative synthesis

Figure 27 illustrates a mechanism for digital agency dynamics in distributed digital innovation where the instantiation of digital agency dynamics as a result of local adaptation accumulate into organisational transformations, which in turn changes the conditions for innovation networks thus spurring the need for additional local adaptation.

The mechanism of double-cumulative synthesis proposes that radical organisational transformations often happen under circumstances of controversy and conflict. Controversy occurs as at least two parties, one of which proposes a new innovation and another stakeholder opposing, envision diverging outcomes of the local adaptation due to conflicting agendas and positions in the innovation network. This forces a synthesis of the original proposal that mitigates resistance from opposing actors. For example, when frontline support managers propose a service level change in the form of a mobile information app. This app is in direct conflict with existing IT and information security policies, why IT and information security teams rejected it. Enrolling the development team in considering a technical solution that accommodated both the initial proposal and the opposition from security stewards then produced the synthesis resulting in a radical shift in IT architecture from a single monolithic server to a modular infrastructure of interconnected servers serving different purposes.

This conflict appears to be precipitated by a shift in the structure of the innovation network resulting from the effects of digital transformation, which includes distribution of access to innovation in technological, knowledge and control related dimensions. This shift in innovation network structure, in turn, diminishes the infrastructure owner's ability to control the distribution of access to further innovation. This mechanism creates wakes of innovation (Boland et al. 2007) cascading into radical transformations such as that of frontline customer service at Barclays described in this thesis. This is in essence the mechanism of double-cumulative synthesis; distributed micro-level actions accumulating into local adaptations that, in turn, accumulate into organisational transformations.

Having discussed the key elements of the theory of double-cumulative synthesis, I now move on to consider the possible application of this theory in contexts beyond the one presented in this research.

6.4. Double Cumulative Synthesis as Morphogenesis

The research questions that guide this research are framed to explicate the characteristics, structure and agency dynamics of distributed digital innovation. In this light, and in reading in the context of the IS field, it is easy to read into this research the contours of a structuration theory approach. However, I will here argue that structuration theory as proposed by Anthony Giddens (1979, 1984), and later adapted to the IS field, has important shortcomings in describing the process of distributed digital innovation and propose a different theoretical grounding in morphogenesis. In the following I will outline two important shortcomings of structuration theory; the analytical inseparability of agency and technology and the absence of process outcomes and stasis. In turn I will discuss how each of these shortcomings are inconsistent with the findings of this thesis and propose an alternative theoretical grounding in the morphogenetic approach as presented by Margaret Archer (2010) based on general systems theory (e.g. Von Bertalanffy and Rapoport 1956; Kast and Rosenzweig 1972).

First, structuration theory is fundamentally concerned with breaking down the dichotomies between structure and agency and thus explaining social phenomena not as determined by their structure or purely as a products of agency, but as the product of mutual constitutive forces of structure and agency (Giddens 1984; Jones and Karsten 2008). Structuration theory asserts that technology come into existence only through being enacted by human actors in mutually constituent sociomaterial practices (Boudreau and Robey 2005; Pickering et al. 1996; Orlikowski 2007; Orlikowski and Scott 2008). That is, humans perform technologies and thereby meld their agency with the structure of the material artefacts (da Cunha and Orlikowski 2008). Some scholars use the notion of entanglement to capture the intertwinement of material structure and human agency, i.e., they are inextricably related and therefore mutually constitutive of each other. This means that agency and technology cannot be seen as analytically separate entities and that the unit of analysis for structuration theory is confined to the practices in which structures are enacted. This is what structuration theory refers to as 'duality of structure', i.e. overcoming the dualism of structure and agency (Giddens 1979; Orlikowski 1992).

While the motivation of structuration theory to avoid myopic views of either structural or social determinism, the notion of duality of structure and entanglement make it difficult to analyse the technological and organisational outcomes of distributed digital innovation outside the context of human agency. This effectively blinds the analysis for focusing on the *emergence* of structure from distributed actions. By seeing actions and structures as entangled and mutually constitutive, action is always an element of structure and vice versa. What the theory of double-cumulative synthesis developed in this research proposes is that organisational and technological structures emerge from distributed small-scale actions, that cannot be described as the sum of distributed actions, but rather as a consequence of agency configurations with emergent characteristics. In place of structuration, I will therefore argue that the findings of this thesis are more compatible with a morphogenetic approach.

Morphogenesis, like structuration, is concerned with the complex interactions that produce transformations in the form, structure or state of a system. However, in contrast to structuration it has an end product, referred to as ‘structural elaboration’, which is significantly different from the description of social systems in structuration theory as merely a ‘visible pattern’. Specifically, structuration theory focuses exclusively on analysing recurrent social practices, where general systems theory emphasises that elaborated structures has emergent properties which cannot be reduced to practices alone. This fundamental difference is especially important in the context of distributed digital innovation as different practices in various heterogeneous contexts interact to produce emergent structures at the organisational level with distinct properties that cannot be reduced to the sum of distributed practices.

Second, structuration theory has been adapted to explain the process by which technology and organisations are shaped in both organisation science and IS research in broadly speaking two ways: through adaptive structuration theory (AST) and in the shape of research on the duality of technology (Jones and Karsten 2008). While both offer good theoretical model for analysing the continuous interaction between technology and organisations, they both fall short of capturing the *process* of emergence of digital innovations from a distributed social system. Adaptive structuration theory proposes that a technology with specific features and characteristics will be continuously enacted based on how they are appropriated in a specific organisational context with a given set of evolving structures (DeSanctis and Poole 1994; Markus and Silver 2008). Duality of technology views explain how human agency, technology and institutional properties are mutually constituent through continuous and on-going interactions (Orlikowski 1992). Both theories offer models of structuration processes between actions technology and organisations, and both build on the same fundamental assertion made by Giddens that *"…social systems only exist through their continuous structuration in the course of time"* (1979, p. 217). However, there is little to be found in structuration theory or indeed in its derivatives about the emergence of structure *over time*.

This notion of absolute synchrony is contrasted in the morphogenetic proposition that structure and action logically operate over different time periods (Archer 2010). Specifically, morphogenesis argues that structure logically precedes the action or actions which transform it, and that structural elaboration logically follows those actions. This sequential relation between structure and agency in a chain of structure – agency – structural elaboration is more consistent with the findings in this thesis of a proposition – opposition – synthesis sequence of double cumulative synthesis.

In summary, there are at least two elements of the theory of double-cumulative synthesis proposed in this thesis that favour the morphogenesis approach over structuration theory as a theoretical grounding. First, double-cumulative synthesis relies on emergence. This means that structures and agency should indeed be analytically separate entities as emergent organisational and technological transformations have properties that cannot be reduced to practices. Second, double-cumulative synthesis describes a process in which structure precedes action that in turn generates outcomes in the for of structural elaboration of technological and organisational transformation.

Having contoured a theoretical integration of the findings of this thesis into structuration theory and general systems theory, the next section considers the scope of application for the theory of double-cumulative synthesis.

6.5 Extending the Theory to Other Contexts

Having established the main theoretical and methodological findings of the case analysis, the suitability of this tentative theory of distributed digital innovation for applications in contexts beyond the one used in this thesis is now investigated. The purpose of this investigation is to indicate a space of contexts in which application of the generated theory could possibly be attempted.

Of course, there is the likelihood of extraneous factors not explained in this thesis, but which might contradict the findings discussed in this chapter. Baring this in mind, this section starts by describing key characteristics of the phenomenon under investigation in this case before discussing the possibility of applying the theory of double-cumulative synthesis to other empirical contexts by comparing the characteristics of similar empirical settings to those explained in the Barclays case study.

The object of analysis for this thesis, i.e. the radical transformation of frontline customer service at Barclays through digitalisation, has several identifying characteristics. This research is concerned with explaining the process by which multiple distributed actions involving people and digital technology accumulate into a radical transformation of customer service. The development of digital technology serves as a catalyst and enabler for the distribution of innovation activities as it distributes 1) access to technical innovation by being based on a layered modular infrastructure, 2) the mobilisation and application of ideas and competences across the innovation network and finally 3) it distributes control of local adaptation as well as trajectory level transformations, thus involving a much wider range of actants. Moreover, the inclusion of new stakeholder groups and the development of a modular layered architecture seem to be crucial prerequisites for applying the generated theory.

The first area to consider is whether the theory of double-cumulative synthesis could be extended to other areas of Barclays' service offerings such as investment banking targeted at financial investors and payment processing targeted mainly at retail outlets. Payment processing appears to have the potential to accommodate the prerequisites for applying the model. The existing technological infrastructures for payment processing and share trading are under pressure from layered modular infrastructures such as the Blockchain infrastructure that for example accommodates the digital Bitcoin currency.

In one example, NASDAQ has, as a means of facilitating trade in private companies, recently adopted Blockchain technology and similar efforts are being made to adopt Blockchain technology for payment processing, including that of the development of Bitcoin. In both cases, the Blockchain would represent a layered modular IT architecture that effectively works as an API on which additional distributed stakeholder groups could generate local adaptations with the potential to accumulate into radical transformations of payment and investment services. This means that the framework could also be extended to involve other types of innovations other than those directed at customer service.

The second area of application to consider is whether the theory of double-cumulative synthesis could be applied in other industries beyond financial services. As the conditions of layered modular architecture and stakeholder inclusion are present in multiple other contexts, there is a possibility that the framework could be applied to other industries. However, it must be noted that the described prerequisites are more likely to be found in similar retail service organisations such as insurance or pension providers than in vastly different industries such as manufacturing or professional services. In the case of manufacturing companies, the materiality of production machinery and physical goods provide heavy constraints on the level of stakeholder involvement and technological flexibility, making it less likely to find a process that would be suitable example of double-cumulative synthesis. To the other extreme are professional service organisations where, in some cases, technological and stakeholder structures are in such flux that it would be difficult to distinguish a shared technological infrastructure and draw a meaningful distinction between which actors are included, and which are not.

The theory would not be applicable to e-government or any other service context in which centralised control is prerogative. In cases involving sensitive data that cannot, even though they might be encrypted, be distributed across multiple stakeholder domains the framework would seize to apply as centralised technological infrastructures, development processes and control structures are needed. At Barclays, the model applied as long as the data being shared pertained to the collaboration between employees at the bank. However, this represented a new branch of its trajectory that did not include sensitive customer information such as account information and personal data. This type of information is inherently static and should not be subjected to local adaptations or contestation and controversy.

This proposes that the theory developed in this thesis can be used to explain and describe the dynamics of distributed digital innovation in general, as long as it matches the conditions of a layered modular architecture and inclusion of additional stakeholder groups.

6.6 Summary of Discussion

This chapter has discussed the analytical findings of the empirical case study in order to build a theory of agency dynamics in distributed digital innovation.

First, it presented substantive conceptualisations of the organisational transformations, innovation networks, and agency dynamics at play in the radical transformation of frontline customer service at Barclays. Having conceptualised the substantive area of the case analysis, the emerging concepts were integrated with existing innovation theory and discussed as a theory of cumulative synthesis. On the basis of this theoretical integration, a mechanism of 'double-cumulative synthesis' was presented and substantiated as a tentative formal theory of the agency dynamics of distributed digital innovation. Finally, the scope of the theory was assessed by discussing the possibility for the application of the theory of double-cumulative synthesis in contexts other than at Barclays based on the conditions of the presence of a layered modular digital infrastructure and viability of inclusion of diverse stakeholders in the innovation process.

The following chapter moves on to discuss the methodological implications of the theory of double-cumulative synthesis in changing the scope and perspective from which computational research can leverage the extensive digital traces recorded through distributed digital innovation.

7. METHODOLOGICAL IMPLICATIONS

It is a well-established notion that analysis of digital innovation in the broadest sense is by nature directed at exploring a novel proposition in the form of the introduction of a new innovation (Latour 1991a; Venturini 2009), a controversy (Madsen 2012; Meyer 2009; Ricci 2010) or a question to be researched such as the introduction of a new technology, actor, idea, or a shift in the institutional context (Henfridsson and Yoo 2013). While some initial efforts towards a methodology for such research have been made (Latour 1991a; Okada et al. 2008; Venturini 2012; Venturini and Latour 2010), the materiality of digital technology and the implications of digital innovation have so far received only sporadic attention in the literature. The following paragraphs first discuss distributed digital innovation as a research setting and then moves on to explore the consequences of digital innovation in general, and specifically of digital trace data, for research methodology.

7.1 The Traces of Distributed Digital Innovation

The digitisation of once physical environments and practices has been identified as a crucial frontier in researching the organisation of social activities in an increasingly digital world (Yoo and Lyytinen 2010). As digital technology increasingly permeates into physical environments (Lyytinen et al. 2002), an abundance of practices that were once confined to a physical location are now taking place in a networked digital innovation.

Examples of emerging digital innovations include mobile and digital workplaces, online movements and activism, e-government, distributed product design and innovation settings as well as open source communities. What these diverse environments have in common is a surprising inability to answer seemingly simple questions based on existing analytical methods including questions like why do our customers buy our product, how effective are online petitions, and who are our most valuable employees? This presents what one could call a data overload paradox: an explosive increase in the volume and scope of digital trace data leads to an inability to, by means of existing variance-based methods, answer seemingly simple questions.

The reasons for the data overload paradox are to be found in the materiality of emerging digital innovations. Digital innovations consist of large volumes of digital trace data (Newell and Marabelli 2015) produced by the increasing digitalisation of social contexts (Hedman et al. 2013). Datafication of social actions and relations involves digital agents in the form of algorithms that have recently evolved from processing sequential computational calculations to performing machine learning processes involving interpretation, decision-making and translation. These processes all operate through the medium of digital trace data (Andersen et al. 2016; Hedman et al. 2013; Howison et al. 2011; Venturini 2012).

This means that the volume of available data accumulates at an increasing rate thus reinforcing the process of datafication. Increasing datafication in turn leads to an explosion of the scope and range of digital agents as ever more trace data is produced at the same time as increasing global connectivity of information systems and digital infrastructures widens the range of data repositories accessible to digital agents. This process leads to an immense increase in data volumes that essentially serves as the fuel that catalyses the activities of digital agents.

Consequently, emerging digital innovations follow different organising logics than physical environments (Yoo et al. 2010). This has at least two important consequences. First, the programmability and flexibility of the core architecture of digital technology means that processes of digital innovations are continuously shaped and adapted through the social practices they support over time (Henfridsson et al. 2009). This means that research into digital innovation must focus on relations rather than entities and process rather than state. Secondly, people, resources and information are connected in widely distributed and heterogeneous networks that span geographical, organisational and social boundaries, and affect multiple social contexts (Lindgren et al. 2008; Yoo et al. 2008). For example, organisations increasingly rely on external data as previously internal processes are distributed in digital ecosystems (Selander et al. 2010).

While these consequences of digitisation present exciting opportunities, they also present significant challenges to existing research methodology in all phases from data collection and analysis to problems of inference and theory building based on digital traces. Previous studies of digital innovation have emphasised the need for a new methodological approach (Latour 1991a, 1996), but so far attempts have been fragmented and confined to specific contexts.

Recent developments in the digital methodology of actor networks point to the usefulness of computational methods in unravelling the complexity of distributed innovation processes (Venturini 2012; Venturini and Latour 2010). The a priori nature of found digital trace data allows researchers to study social interaction processes involving multiple distributed actants at a resolution that is sensitive to individual level effects.

However, the increase in datafication and proliferation of computing power means that it is now viable to develop much more granular methods for analysing distributed socio-technical processes in great detail, and specifically those of distributed digital innovation. Before embarking on this task, however, it is important to elucidate some of the most important consequences of analysing digital traces of distributed digital innovation on the broader methodological approach.

7.2 Research Consequences of Digital Trace Data

Digital trace data have been named the raw material for a 'twenty-first century science' (Watts 2007). Digital traces have at least three identifying characteristics, which set them apart from previously known data sources in the social sciences (Venturini 2012): First, they are recorded as a by-product of actual social interactions rather than collected using a predesigned data collection instrument. Second, they represent interactions between sociotechnical actors why they can be said to be relational in nature, and finally, they are longitudinal in that their sequence and co-occurrence is recorded.

First, digital traces are the manifestations of interactions related to digital innovations in the shape of e.g. status updates, comments, emails, server logs etc. These diverse manifestations of trace data all represent by-products of actual social activities rather than produced data constructed through a designed research instrument (Howison et al. 2011). This allows researchers to study social interaction processes involving millions of people at a resolution that is sensitive to individual level effects. While for natural scientist the availability of large quantities of found data has been commonplace, it represents a great leap forward for the social sciences where *"up to now, access to collective phenomena has always been both incomplete and expensive"* (Venturini and Latour 2010).

Secondly, trace data are event-based and relational data. This means that instead of discrete and autonomous samples, digital traces represent events of social interactions. For example, in a traditional survey of social interactions, researchers typically ask directly about social relationships, relying on the respondents to recall and interpret their own interactions to summarise a social relationship. This generates obvious validity issues as any information about a certain event is interpreted and summarised to the researcher, and the volume of data that can feasibly be collected is limited. Digital traces provide rich and directly accessible accounts of the micro-events that make up the emergence and evolution of digitally distributed social contexts (Borgatti et al. 2009). By exploiting the large-scale production of expansive digital traces of the conditions, properties, movements and interactions of digital innovations (Yoo et al. 2010) researchers can establish with great precision the events that manifest in social relations and networks.

The final characteristic of trace data is that they are longitudinal data, because the events that make it up occur over time. This has some rather profound consequences for the way in which researchers and managers can think about inference, evidence and generalisation. Previous analyses of digital traces within IS research have mainly focused on statistical and more static hypothesis testing (Hedman et al. 2013). While this research has revealed a great deal of insights into the antecedents and consequences of social phenomena by utilising overwhelming availability of variables that can be measured in digital traces, it fails to account for the social processes and sociomaterial practices behind the emergence, development and proliferation of social issues over time (Langley 1999; W. J. Orlikowski 2007).

Specifically, where variance based research focuses mainly on linear relations between autonomous variables, process based research explores the network dynamics of relations and events that make up social issues (Van de Ven 2007). In this way digital traces data open for a shift in research paradigm to a process research approach which *"…involves considering phenomena dynamically – in terms of movement, activity, events, change and temporal evolution*" (Langley 2007, p. 271) at a hereto unseen scale and level of detail. Figure 28 illustrates the difference between variance based and process research paradigms.

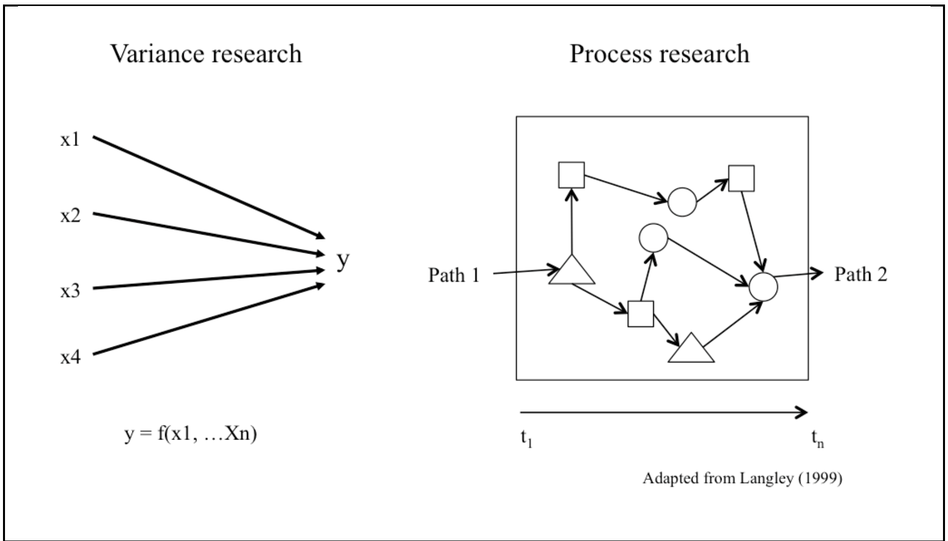


Figure 28. Variance vs. process research paradigms

Where variance based research is concerned with identifying the antecedents explaining a dependent variable, process research is focused on describing the dynamics by which trajectories emerge, shift and disperse over time. Given the characteristics of digital traces discussed above, the latter paradigm is best suited for analysing distributed digital innovation. As digital traces represent interactional relations between actors and are accumulated over time, they make visible social processes that are difficult or impossible to study using traditional research methods (Agarwal et al. 2008). Addressing the lack of digital, non-variance based research in the IS literature identified by Hedman et al. (2013) the next section further develops a relational process approach to grounded analysis of distributed digital innovation.

7.3 Building Computational Methods for Distributed Digital Innovation

At least two aspects are salient for materialising a more rigid method of researching distributed digital innovation: relational approaches beyond social network analysis e.g. involving relations between semantic constructs and human interactions, and longitudinal approaches for unveiling the shaping mechanisms of distributed digital trajectories.

For example, in a traditional survey of social interactions, researchers typically ask directly about social relationships, relying on the respondents to recall and interpret their own interactions to summarise a social relationship. This generates obvious validity issues as any information about a certain event is interpreted and summarised to the researcher, and limits the volume of data that can feasibly be collected. Digital traces provide rich and directly accessible accounts of the micro events that make up the emergence and evolution of social networks (Borgatti et al. 2009). By exploiting the large-scale production of expansive digital traces of the conditions, properties, movements and interactions of digital innovations (Yoo et al. 2010) we can establish with great precision the sequence of events that manifest in social relations and networks.

This longitudinal nature of digital innovation processes has some rather profound consequences for the way in which researchers and managers can think about inference, evidence and generalisation. Previous analyses of digital traces within IS research have mainly focused on statistical and more static hypothesis testing (Hedman et al. 2013).

While this research has revealed a great deal of insights into the antecedents and consequences of social phenomena by utilizing overwhelming availability of variables that can be measured in digital traces, it fails to account for the social processes and sociomaterial practices (W. J. Orlikowski 2007) behind the emergence, development and proliferation of social issues over time (Langley 1999). Specifically, where variance based research focuses mainly on linear relations between autonomous variables, process based research explores the micro-dynamics of relations and events that make up social issues (Van de Ven 2007). By including the notion of algorithmic agency in research data open for a shift in research paradigm to a process research approach which *"...involves considering phenomena dynamically – in terms of movement, activity, events, change and temporal evolution"* (Langley 2007, p. 271) at a hereto unseen scale and level of detail.

The empirical analysis presented in this research has attempted to apply these characteristics to build a novel approach for studying distributed digital phenomena. The grounded computational analysis approach developed in chapter 3 outlines a way forward for combining the relational and longitudinal characteristics of such processes in a research framework that is practically applicable to any digital trace record of distributed innovation processes.

However, this is merely a first crude step on a long journey to develop new methodological approaches for researching an increasingly connected and digital world. The hope is for this first step to provide some direction for future endeavours into a world of fundamentally different research practices. Zooming in for a closer look at the different research practices associated with computational analysis, computational methods can be divided into three categories based on the degree to which computers are involved in generating data analytical outcomes, applying computational operations and making analytical decisions.

Level 1 Computational Analysis: Pattern Recognition

The first level of computational analysis, which in this research is implemented as grounded computational analysis, involves applying computational techniques at the level of data exploration. At this level, computational techniques are applied to collect and represent large volumes of digital trace data in a way that makes it accessible to interpretation by a human researcher. The computer in this respect serves as a tool to process large quantities of data. However, even then computers possess a number of inherent biases that should be considered when applying computational techniques.

First, the sources of digital trace data should be carefully considered when evaluating a source of digital trace data (Howison et al. 2011). Mining data from online community sites or social collaboration platforms means that the data collected import the values and norms built into the design of the specific digital environment. Each digital environment has been designed in such a way as to facilitate specific types of interaction and discourage others and so the specific characteristics of the data source must be considered as an analytical bias.

Second, statistical techniques and computational methods including natural language processing and social network analysis are biased towards data units that conform to the structure determined by the specific data source. Anomalies in the form of interactions that break with the conventions that are embedded in the design of the data source are typically either filtered out in data unit separation process or will be given less significance when measured on a discrete scale. This means that data units that are potentially semantically important, but do not conform to the intended structure of the data source to some extent are at a risk of being neglected in the use of computational techniques.

That being said, computational methods can prove invaluable tool in detecting salient patterns in large volumes of digital trace data. When researching distributed digital innovation specifically, the reach and scalability of computational techniques for data exploration makes it a key instrument for opening the black box of distributed digital processes and taking the perspective of the information system.

Level 2 Computational Analysis: Predictive Modelling

The second level of computational analysis involves the application of sophisticated algorithms such as deep learning (Flach 2012), genetic algorithms (Goldberg and Holland 1988) and neural networks (Bishop and Nasrabadi 2006; Eletter et al. 2010) in forecasting and building predictive models.

In common for this type of computational approaches is that they perform computational operations on the data and evaluate the results of each operation in relation to a specific pre-determined intended outcome. This way level two algorithms build predictive models of a phenomenon in question through learning from automated computational operations through a process of trial and error. This results in a model that is able to predict the outcome of a given process within a limited empirical scope.

While such methods have been applied in fields such as financial decision making (Eletter et al. 2010), they have a number of limitations that must be addressed when considering them in the context of distributed digital innovation. First, they assume that the data input is uniform and static over time. Combined with the assumption that the phenomenon itself, i.e. the outcome variable, is static, this opens a number of issues that must be addressed before level two techniques can be applied to distributed digital innovation.

In the context of distributed innovation processes where emergent and localised micro-dynamics accumulate into emergent transformations (Geels 2002, 2005; Usher 1955) leads to a process of technological 'transfiguration' (Kallinikos et al. 2013), the longitudinal and empirical scope of the model must be rigorously addressed. However, such methods hold the potential to play a key role in understanding the emergence of patterns in well-defined empirical contexts of distributed digital innovation.

Level 3 Computational Analysis: Computer Simulation

The third level of computational analysis involves computers in a much more reflective role why it is also the most controversial and under-developed area of computational analysis. At this level, the analyses performed are in the form of computational experiments based on assumptions drawn from identified patterns and predictive modelling. In this sense the tables have turned in comparison to traditional methods treating the IT artefact as exogenous. The computer has to an extent taken over the generation of digital traces and computational operations and from that perspective treats human interactions as exogenous and secondary to the simulated environment.

Computer simulations modelling of complex systems such as agent based models can be used to better understand the mechanisms that lead to emergence of technological trajectories (Baum and Silverman 2001; Nan 2011). However, linking the macro-level mechanisms identified in computer simulations to specific empirical entities is still a problem that must be addressed in a research design before the full potential of computational analysis of distributed digital innovation can be actualised.

7.4 Chapter Summary

Building on the methodological approach of grounded computational analysis presented in chapter 3, this chapter has attempted to outline some of the key implications of computational analysis on analysing distributed digital innovation.

By identifying the defining characteristics of digital trace data, a number of profound research consequences were discussed including the need for a relational and longitudinal digital methodology, including the shift in the use of large volumes of quantifiable data from hypothesis testing to building process theory. Furthermore, it has discussed the potential relevance of three levels of computational analysis involving pattern recognition, predictive modelling and computer simulation in researching distributed digital phenomena.

8. CONCLUSIONS

This final chapter concludes the thesis. It first provides an overview of the research and analyses before presenting a summary of the findings. It then moves on to synthesise the findings into contributions to theory, method and practice. Finally, the validity and limitations of the research are discussed before the thesis closes with considerations of possible future research and final remarks.

8.1 Overview of Thesis and Summary of Findings

The research presented in this thesis addresses on-going research streams within information systems, and management theory in general, concerning digital innovation. The emerging field of digital innovation includes a growing body of literature ranging from design of digital artefacts to organisational and industry transformations related to digital technology. At both ends of that spectrum there is a growing recognition that digital innovation is a distributed, and therefore to some extent emergent, process, and it is this specific aspect of the digital innovation literature this research seeks to address.

8.1.1 Background and Research Questions

The specific focus of this thesis is on the agency dynamics by which multiple small-scale actions accumulate into radical organisational transformations in the context of distributed digital innovation. There are processes of digital innovation, even ones resulting in radical transformations, which are tightly managed and governed by a centralised group of managers and designers. This is typically the case in life-critical systems or systems containing highly sensitive information. The case presented in this thesis focuses on an instance of distributed digital innovation that breaks from such a centralised structure to emerge into a radical service and organisational transformation. Such a process in characterised by at least two elements; the distribution of micro-level actions in heterogeneous innovation networks, and the nature and dynamics of distributed actions that accumulate into radical transformations.

Although positioned within this empirical scope, this research is not primarily concerned with theorising the overall process of trajectory shaping through path creation (e.g. Garud and Karnoe 2001; Henfridsson et al. 2009; Singh and Mathiassen 2015). It focuses instead on identifying and conceptualising how small-scale distributed actions accumulate into radical transformations. While it has already been established within the path creation literature that distributed actions lead to macro-level transformations (Garud and Karnøe 2003) and that digital innovation takes place in distributed innovation networks (Boland et al. 2007; Yoo et al. 2008), the specific structures of innovation networks and the particular qualities and characteristics of micro-level actions that accumulate into radical transformations is where this thesis aims to provide a theoretical contribution. It does so by answering the overarching research question addressing these particular elements of network structure and dynamics of distributed agency:

How do digitally distributed actions lead to radical organisational transformation?

This research question was then broken down into three sub-questions each addressing three specific elements of the contribution target. The first research question is related to the process by which digitally enabled transformations occur as a distributed rather than a centralised process, resulting in the formulation of the question:

Q1: What are the characteristics of digitally enabled organisational transformation?

The second research question investigates the ways in which distributed digital innovation is distributed in innovation networks. The aim was to establish the ways in which structure and characteristics of innovation networks affect the outcomes of distributed digital innovation. These issues were addressed in the second sub-question:

Q2: How does the distributed structure of digital innovation networks lead to organisational transformation?

Following this, the final research question addresses the nature of this dynamics and surmises its scope and mechanisms. Specifically, it investigates the dynamics by which distributed micro-level actions fail or succeed in affecting transformation the organisational level. This was formulated in the third research question:

Q3: What are the characteristics and dynamics of distributed actions that affect radical organisational transformation?

The following sections will elaborate how and to what extent these research questions were addressed throughout the thesis. After a brief recapitulation of the research approach taken in generating this research, the most important empirical and theoretical findings are presented before presenting in greater details the theoretical, methodological and practice related contributions resulting from the thesis.

8.1.2 Approach to Research

Data concerning the evolution of the BankApp project and the radical transformation of retail banking at Barclays was collected and analysed in three iterations. Barclays was chosen as a research setting because it matched the criterion of providing a clear diversion from a traditional centralised IT infrastructure and because the BankApp project provides an elaborate account of distributed innovation of a digital platform resulting in radical transformation of a key business area.

This process of distributed innovation was expressed in a series of events involving controversies between localised actors as they negotiate the local adaptations of organisational changes. The empirical data included in the two-year longitudinal and multi-method research design was comprised of interview study, document analysis and field observations as well as larger volumes of digital trace records of interactions relating to the project. The latter data source recorded a multitude of micro-level actions in great detail, which added breath and texture to the analysis of agency dynamics of the distributed digital innovation process. The analysis was structured in three iterations to capture the emerging transformations, the distribution of the innovation network, and the dynamics and characteristics of distributed actions.

First, a detailed account of the critical transformations through which the project in a significant way changed retail banking practices at Barclays was presented. Adopting a theoretical lens based in the technological trajectories and path creation literature (Garud and Karnoe 2001; Geels 2002, 2005; Sydow et al. 2009), path critical events were defined as instances where multiple distributed actions combine to generate organisation-level outcomes. Based on existing literature on technology evolution (Garud and Rappa 1994) and layered modular architecture (Henfridsson et al. 2009; Yoo et al. 2010), these outcomes where theorised to affect either artefacts, knowledge resources, or organisational structures. This analysis addressed the first research question regarding the nature of the distributed digital innovation process.

Having established a general sequence of episodes of organisational transformation, the structural evolution and constituent parts of the innovation network (Yoo et al. 2008; Yoo et al. 2010) were analysed for each organisational transformation using social network analysis (Howison et al. 2011; Prell 2012; Scott 1994). Combining the results of the innovation network analysis with thick descriptions derived from the qualitative coding in the previous iteration, a general understanding was generated of how the involvement of different kinds of actors in specific innovation network structures affected organisation-level transformations.

Finally, the dynamics of the specific micro-level actions involved in each organisational transformation were identified using natural language processing techniques such as latent semantic analysis (Deerwester et al. 1990; Landauer et al. 1998; Wild and Stahl 2007) to analyse digital trace data. Combining the computational analyses with qualitative coding of the remaining data sources allowed for the generation of a typology of the last remaining analytical component of the research design, the characteristics of small-scale distributed actions. By tracing occurrences of specific types of actions, the agency dynamics that affected organisational transformations could be established. This last iteration related to the third research question addressing the agency dynamics of distributed digital innovation that lead to organisational transformation.

The methodological reflections and development work put into the generation of the research design manifested as the grounded computational analysis. Grounded computational analysis describes a methodological framework that combines grounded theory methods (Glaser and Strauss 1967; Urquhart 2012; Vaast and Walsham 2011) and data analysis in the natural sciences, more specifically in biochemistry (Klie 2011) and genetic sequencing (Kumar et al. 2001). This finding relates to establishing the appropriate research methods and techniques that can be applied to empirically investigate distributed digital innovation. As it represents a methodological rather than theoretical contribution, it is not formulated in a separate research question, but none the same it seems significant enough as a contribution to digital innovation research that it deserves to be mentioned in this context.

8.1.3 Empirical Findings

The findings of this research can, broadly speaking, be divided into two categories. The first category contains findings, which are based on empirical data as described primarily in the analysis of distributed digital innovation chapter (chapter 5). The second category includes findings of a more theoretical nature that are derived from the discussion and theory building chapter (chapter 6).

The findings that are derived from empirical analysis fell into three further sets of contributions matching the three sub research questions. The first of these sets of findings largely serves to describe the trajectory of the radical transformation of frontline customer service in retail banking at Barclays. The aim was to establish the sequence of critical events accumulating into this organisational transformation. A non-exhaustive sequence of 14 critical events was found to accumulate into five significant transformation in the trajectory of retail banking at Barclays relating to changes to artefacts, knowledge resources, or organisational structures. The five organisational transformations and 14 accumulation events were identified through initial interview and document analyses. It was found that each accumulation event leading to an organisational transformation contained a specific set of elements, namely a proposition for a new innovation, some form of opposition from at least one other actor and a synthesis adapting the proposition to localised agendas and conditions.

The second set of findings explains how the characteristics and structure of the innovation network of distributed actions relate to each organisational transformation. The initial network analysis of the digital trace data revealed participation by a highly heterogeneous group of actors in each organisational transformation including human actors, digital agents and digitally emergent actants such as topical and geographical groups and technologies. As the transformation evolved, more and more diverse actants were mobilised causing a self-reinforcing process where more human actors mobilised more digital actants that in turn mobilise more human actors and so on.

Interestingly, the number of actors involved did not translate directly into organisation-level transformations. This was only found to be the case to the extent that two conditions were met: 1) the presence of all three components of organisational transformations identified above and 2) the enactment of actual interaction and negotiation between actors represented through high density of clusters in the corresponding innovation network. This suggests that high volumes of sporadic and semi-autonomous actions by a large number of actors are not sufficient to facilitate significant transformations. Continuous interaction and negotiation between actors are prerequisite. Also, these micro-level actions must include proposition, opposition and synthesis. Thereby the empirical findings suggest that any proposition that is absent of opposition is not sufficiently radical to affect significant synthesis and thereby lead to transformation.

The last set of empirical findings are concerned with explaining the nature of the distributed micro-level actions and the dynamics by which they accumulate into radical organisational transformations. This set of findings was derived by applying natural language processing and clustering techniques to the content of the interactions that made up the innovation network and combining it with the coding from the first round of qualitative analysis.

The analysis revealed 2,016 potential instances of semantic concepts that all related to proposition, opposition and some degree of synthesis. 1,194 of these instances were positively related to digital innovation in the artefact, knowledge, or organisational dimensions. Applying k-means clustering to the sample of pertinent interactions actions and then comparing the resulting clusters with existing qualitative coding provided a typology of five distinct clusters of micro-level actions. Computing the compositions of these agency dynamics for each organisational transformation revealed that each specific transformation was composed of a unique configuration of agency dynamics. A general pattern, or dynamic, that was revealed showed how the digital innovation process starts out by enabling transformations emerging in the technological dimension before evolving into first knowledge related and finally organisational transformations.

Moreover, specific agency configurations were found to be more effective than others at certain points in the transformation process, suggesting that sequence and context are crucial for a certain agency configuration to affect organisational transformation. Having reiterated the empirical findings of this thesis, I now move on to summarise the theoretical findings that can be derived from the analyses.

8.1.4 Theoretical Findings

The discussion and findings chapter (chapter 6) recasts the empirical findings as a tentative theory of agency dynamics in distributed digital innovation before applying this tentative theory to the case of Barclays itself and relating it to existing innovation theory. The resulting theory of double-cumulative synthesis presented in chapter 6 turns research attention to the emergent process by which micro-level actions accumulate into radical organisational transformations. It was suggested that Usher's concept of 'acts of insight' (1955) and the related notion of 'mindful deviation' found in path creation literature (Garud and Karnøe 2001) provide a basis for distinguishing between routine actions and actions that possess the potential to accumulate into organisational-level transformations, specifically in the case of the emergent transformation of retail banking at Barclays.

On this basis, a typology of five agency dynamics of distributed digital innovation were identified from micro-level actions with transformational potential. Each agency dynamic refers to a semantically distinct thread of interactions following the pattern of proposition, opposition and synthesis through controversy or negotiation. The agency dynamics identified in the emergence of BankApp at

Barclays was 1) sub-optimality correction 2) routine disruption, 3) aspirational refocusing, 4) governance translation and 5) organisational restructuring. These agency dynamics provide a vocabulary for conceptualising the mechanism by which distributed small-scale actions affect radical transformations of retail banking like the ones presented in the case of BankApp. This vocabulary was then used to establish the transformational potential of each agency dynamics. Thereby the theoretical finding emerges that various agency dynamics combine into specific configurations at certain time in the course of the trajectory to affect organisational transformations to technological, cognitive and control related structures.

Following from this, tentative theoretical explanations of the evolution of the organisational-level transformations can be proposed. In the case of Barclays, the transformation process evolved in a way so that each dimension of distributed digital innovation was transformed in a sequence beginning with technological transformations of the IT infrastructure to a layered modular architecture before moving on to changing the way in which knowledge resources and ideas were disseminated throughout the organisation before finally emerging into radical transformations of governance and organisational structures. This finding proposes that the general trajectory of digitalisation follows a set pattern that constraints the potential of certain agency configurations and enhances the cumulative effects of others depending on the stage of the transformation process.

Relating the established theoretical concepts derived from analytical findings to existing innovation theory elucidates the double-cumulative synthesis mechanism that explains how distributed small-scale actions accumulate into radical organisational transformations. The mechanism explains how distributed controversies relating to a set of agency dynamics accumulate into configurations with the potential to, under certain conditions, affect trajectory-level transformations of technological, cognitive and control related structures. Each organisational transformation in turn changes the digital IT infrastructure and thus the structure of the innovation network thus serving as propositions at the micro-level to which distributed actors must adapt. This self-reinforcing generative mechanism (Bygstad 2010; Henfridsson and Bygstad 2013) explains the emergence of radical digital transformations of retail banking at Barclays.

In conclusion, the tentative grounded process theory of agency dynamics in distributed digital innovation presented in this thesis proposes that radical organisational transformations in the context of distributed digital innovation are contingent upon at least the following four factors: a) the sequence of previous organisational transformations emerging from accumulation of multiple micro-level actions; b) the composition and structure of the innovation network in which transformational agency is embedded; c) the presence of proposition, opposition and synthesis in distributed micro-level interactions; d) the specific configurations of enacted agency dynamics.

The following sections discuss in greater detail how these findings represent research contributions to the reference theory, methods and practice field related to this thesis.

8.2 Research Contributions

The aim of the following paragraphs is to distil the contributions to theory, methods and practice made from the research that was recapitulated in the preceding sections. Each of the following sections will present the relevant contributions within the scope of this thesis. After that, the validity and limitations of this research will be addressed to establish the boundaries of these contributions.

8.2.1 Contribution to Theory

The primary theoretical contribution of this thesis is to the information systems literature on distributed digital innovation (Boland et al. 2007; Boudreau 2012; Yoo et al. 2010). The understanding of the process by which distributed small-scale actions accumulate into digital transformations is not well understood in the information systems literature (Yoo et al. 2010). Equally well established is the notion that digital innovation takes place in distributed networks of interconnected and heterogeneous actors, as seen in the growing body of literature on distributed digital innovation (Boland et al. 2007; Yoo et al. 2008; Yoo et al. 2010).

However, despite singular empirical accounts of distributed digital innovation and subsequently some relatively high-level theorising (Yoo et al. 2008), the connection between digitally distributed micro-level actions and organisational transformation remains under researched. In their recent research commentary Grover and Lyytinen (2015) stress the importance for information systems research to adopt the perspective of the digital artefact and from this vantage point generate theory to describe and explain phenomena related to digitalisation.

The primary theoretical contribution of this thesis answers this call by generating a grounded process theory of the dynamics by which small-scale actions distributed in the context of digital technology accumulate into radical organisational transformations. In addition to contributing to the literature on distributed digital innovation, this research adds to the literature on emergent transformations (Geels 2002, 2005; Karnøe and Garud 2012) and distributed agency (Boland et al. 2007; Garud and Karnøe 2003; Yoo et al. 2010) by providing a theoretical perspective of the digital technology itself. This artefact-centric perspective includes a closer investigation of both the actants and actions involved in distributed innovation networks at various scales and levels of the innovation process in general (Venturini 2009) and specifically the nature of innovation networks (Czarniawska 2004), to explain their role in affecting radical yet emergent organisational transformations. With this in mind, the primary theoretical contribution involves describing and explaining the phenomenon of agency dynamics in distributed digital innovation by explicating it on at least two levels: the level of distributed actants and the level of distributed small-scale actions.

The presence of digital traces of distributed small-scale actions allows for such theorisation (Hedman et al. 2013). In relation to the types and nature of actants involved in innovation networks, there is a widespread consensus, at least on a very general level, that digital innovation is enacted by a heterogeneous actors (see e.g. Andersson et al. 2008; Barrett et al. 2015; Tilson et al. 2010). This consensus has not yet been translated into specific conceptualisation of the nature of distributed actants in digital innovation such as those found more broadly in actor-network and path creation theory (Callon 1990; Czarniawska 2014; Karnøe and Buchhorn 2008).

There is therefore a need for empirical research, like that presented in this thesis, both to describe and explain the nature and interconnectivity of actants involved in distributed digital innovation.

This research applies empirical evidence to develop a process understanding of the nature of actors involved in distributed digital innovation beyond exclusively focusing on human agency. It shows how actants emerge as a direct result of automated interactions by algorithmic agents and through a process of enactment of emergent digital actants such as geographies, technologies and topical groups by human actors. Further, it shows how such digital actants play a crucial role in the structure of the distributed innovation network and thereby in affecting the radical transformations observed at the organisational level. This contribution informs digital innovation theory on digital innovation networks (Yoo et al. 2008; Yoo et al. 2010) by providing a deeper understanding of the constituent parts and structural dynamics of doubly distributed networks.

The second set of theoretical contributions adds to the understanding of the dynamics of distributed actions that play out in innovation networks (Czarniawska 2004; Linde et al. 2003; Pentland and Feldman 2007), specifically by conceptualising the various types of distributed agency dynamics at play.

First, the research presented in this thesis provides a tentative typology of digital agency dynamics that provides a vocabulary for conceptualising micro-level actions across multiple distributed contexts. It is the hope that this can provide an initial understanding of the transformational powers of distributed actions beyond labelling them as routines (Gaskin et al. 2014) narratives (Pentland and Feldman 2007). To this end, the findings of this thesis provide an understanding of which specific agency dynamics affect changes to certain dimensions of distributed digital innovation.

In addition to this, the configuration of different types of agency dynamics that combine to affect organisational level transformations of technology, knowledge practices and organisational control structures contribute to the understanding of the mechanisms involved in the accumulation of micro-level actions into organisational transformations.

Seen together, the theoretical contributions provided through this research have potential implications on the conceptualisation related to the debate around path creation and distributed agency dynamics in the context of digitalisation and digitally enabled organisational transformation. These potential theoretical implications are to be further explored through subsequent research efforts on the part of the author.

8.2.2 Contribution to Method

The second area of potential contribution is to the research methods for studying distributed digital innovation. Due to the generative and fluent characteristics of digital technology resulting in the distribution of innovation processes across organisational and geographical boundaries involving multiple heterogeneous actants, a different methodological approach is needed to research such a phenomenon. Taking up this line of thought illuminates a number of challenges in studying the agency dynamics of emergent digitally enabled transformation. In attempting to meet these challenges, at least two potential methodological contributions were generated in the course of this research.

The first methodological contribution relates to research design. The choice of a multi-method research design is not unusual in studying the generative mechanisms of digital innovation (Venkatesh et al. 2013; Zachariadis et al. 2012; Zachariadis et al. 2013). Also the use of innovation networks as a framework for studying distributed agency is well established in the organisation science literature (Czarniawska 2004; Pentland et al. 2011) as is the study of networked controversy as a driver for digital innovation (Latour 1991a; Venturini 2012). Neither of the individual components of the multi-method research design is particularly novel, including traditional qualitative research techniques (Glaser 1978; Glaser and Strauss 1967; Strauss and Corbin 1990), social network analysis (Scott 1988) or latent semantic analysis (Dumais et al. 1988). However, the integration of these techniques and the use of digital trace data in combination with more traditional qualitative data sources in a 'quantifiable qualitative' research design, as opposed to combining variance based and process methods, is a relatively novel approach that potentially informs existing research methods (Hedman et al. 2013; Howison et al. 2011; Venturini and Latour 2010).

The second methodological contribution relates to the use of computational analytical techniques in building inductive and grounded theory. Due to the nature of the distributed digital innovation phenomenon and the aim of generating a grounded process theory of agency dynamics in this context, it was necessary to rethink how the digital trace records (Hedman et al. 2013) of such processes can be leveraged within the framework of the grounded theory method (Urquhart 2012).

The methodological approach developed and implemented in this research to serve this purpose, is presented as 'grounded computational analysis'. The grounded computational analysis framework explicates how quali-quantitative computational analysis (Venturini and Latour 2010) of digital trace data (Hedman et al. 2013) can be leveraged to generate grounded theory. Grounded computational analysis allows researchers to follow a grounded theory research design while leveraging computational techniques to collect and analyse vast digital trace records of distributed social processes taking place in the context of digital technology.

This approach is potentially useful for researchers wanting to capture the scale and multiplicity of distributed social interactions that constitute digital innovation processes, while maintaining contextualisation and semantic texture normally associated with more traditional qualitative research techniques. The only prerequisite is the acquisition by the researcher of basic coding skills.

8.2.3 Contribution to Practice

The third and final area of contribution is related to practice. This research provides insights into the forces besides managerial decree, by which radical digitally enabled transformations occur. Digitalisation of business processes and services is becoming an ever more important strategic advantage for organisations to the point where entire industries are transitioning to a digital-first business model (Tumbas et al. 2015).

Where this has previously been the case for industries such as entertainment and mass media, recently emerging pressure from FinTech start-ups and digital financial infrastructures such as the Bitcoin blockchain force the financial services industry to embark on a similar transition to a digital-first business model. As the digital transformation of retail banking at Barclays represents a case of at least a cross-section of such radical digitalisation relating to frontline customer service, it has the potential to contribute insights that can directly and indirectly be implemented in practice within organisations undergoing a similar process. These insights represent practical contributions in a number of areas related to managing and facilitating organisational digitalisation processes.

First, it provides a general understanding of the sequence of phases in the process of organisational digitalisation as well as an indication of the agency dynamics that can be nurtured at each stage of the process. The findings of this research concerning the sequence of organisational transformations suggest that initial investment in the transition to a layered modular architecture can provide the foundation for facilitating digital innovation within the organisation. Furthermore, the fact that the BankApp project was initiated as a substitute for email for frontline staff and then grew into a mobile news app before eventually emerging as an infrastructure for a radical transformation of retail banking services and organisation, suggests that this initial investment does not need to involve a full scale organisational transformation, but can be limited to a specific well-defined business process and, given appropriate conditions, cascade into the wider organisation. A potential strategic implication of this is that digital innovation does not necessarily require elaborate strategic planning but can, under managerial nurture and direction, emerge from the organisational network. The direct managerial implication is that digital transformation requires facilitation and network orchestration (Dhanarag and Parkhe 2006; Miani and Zachariadis 2011) rather than command-and-control. Dhanarag and Parkhe provide a model of how innovation networks can be orchestrated through positioning a 'hub firm as orchestrator' (2006, p. 661). This involves managing knowledge mobility, innovation appropriability and network stability to facilitate a desired innovation network output. If this model of innovation network orchestration is compared to the case of Barclays, several likenesses appear. First, the focus on increased knowledge mobility, which was the initial purpose for the BankApp project, was implemented through digital technology and through a restructuring of knowledge organisation on the one hand and a shift in the way in which it was disseminated throughout the bank. Knowledge that had previously been communicated top-down through print or intranet sites at specific times was made continuously available through the knowledge base. In addition, the combination of the knowledge base and mobile app made it possible for staff throughout the retail banking division to directly access, request, produce and discuss knowledge content across organisational boundaries. Second, innovation appropriation in the sense of dissemination of the value that is being created at disparate parts of the innovation network to a wide variety of stakeholders was considered very carefully. The decision to position each branch as a hub in each their community was followed through by changing the layout of branches to offer free meeting space and Wi-Fi for the business and civil community alike and by engaging heavily with local stakeholders either in or outside the physical branch. Examples of this includes the 'tea and teach' series of events aimed at educating senior citizens and customers in the use of digital technology for daily tasks including, incidentally, digital banking and the 'coding dojo' events where children and adolescents could attend after hours coding classes at the branch to encourage entrepreneurship. Third, managing network stability in the sense of was achieved by identifying key bridgers and connectors within the network and involving them in developing the digital strategy at headquarters. This shows that although the orchestration of the innovation network at Barclays was in many ways a distributed process, senior management did indeed play a crucial role in selecting and supporting innovations from throughout the network. However, their role has shifted so that *"…leaders need to develop brokering strategies and facilitate links and collaborations between stakeholders"* (Miani and Zachariadis 2011, p. 13) rather than manage by decree and control mechanisms. Indeed, the findings presented in this research show two elements of leadership to have been particularly effective in orchestrating digital transformation at Barclays; a) effective relational leadership and network management and b) implementation of an appropriate organisational structure. In addition to investments in developing and implementing digital technology, the insistence on restructuring the organisation to a structure that accommodates a network-centric innovation setting and diligence in identifying and connecting key stakeholders can be pointed out as crucial leadership tasks in a process of distributed digital transformation.

A final potential implication for practice includes that the methods applied in this thesis provide an analytical framework that can be implemented to measure and monitor processes of digital transformation. By providing specific measurement techniques and metrics as well as a vocabulary for interpreting the results of such analytics, it provides managers with a suite of business intelligence tools aimed specifically to provide evidence that can inform strategic decision-making and facilitation of digital innovation.

8.3 Validity and Research Limitations

In order to assure the quality of research in the sense that the claims made in this thesis are truthful, it must be ensured that the research process and evidence can be reviewed and made accountable to agreed standards (Bauer and Gaskell 2000). The quality criteria and research frameworks for conducting case study research are well established (Yin 2009). However, the research presented in this thesis does not translate directly to the established case study research framework for two reasons. The first and most obvious reason is that the research presented in this thesis is based on a qualitative research methodology, which does not translate well into quantitative research criteria (Bauer and Gaskell 2000). Criteria of reliability and validity in relation to sample population, size and measurements are directly applicable to quantitative, variance-based research (see discussion in chapter 7).

However, in the context of inductive qualitative research, as that presented in this thesis, such criteria can only partially be applied as qualitative research is represented as an interpretation of meaning within a corpus of data where the interpretive process may not be commensurable with validity and reliability measures. Instead, the research presented in this thesis, which is based on a grounded qualitative methodology, should be evaluated from the following criteria for evaluating grounded theory research based on Urquhart et al. (2009): 1) constant comparison 2) iterative conceptualisation, 3) theoretical sampling, 4) scaling up and 5) theoretical integration.

The ambition is that conducting the research following these criteria will ensure the confidence and relevance of the research. Each of the five criteria will now be applied to evaluate the research presented in this thesis. By exposing the weaknesses and limitations of this research in living up to the criteria, it is the hope that potential venues for further research can be uncovered.

Great efforts have been made to document the process of data collection and analysis undertaken in this research (see e.g. appendix 1). Despite the many different data sources and types collected, each data point has been coded to extract meaningful categories at each analytical step, and each instance of data has continuously been compared with other instances of data in the same category. This means that as the theory has developed, each layer of data added through a new round of data collection has been compared with previously collected data in such a way as to expose the categories and codes to rigorous scrutiny.

The process of constructing categories was undertaken in such a way as to iteratively increase the level of abstraction by revisiting and comparing the coding at each step of the analysis. This is done through a process of theoretical coding (Urquhart 2012) in which the relationships between categories, causal and otherwise, are identified. This way an understanding of the relationships between identified theoretical concepts was established. Specifically, theoretical coding was applied in establishing a distinction between micro-level and organisation-level concepts and the interrelations between concepts at each level.

In order to empirically validate each theoretical concepts and their relations, a practice of theoretical sampling (Glaser and Strauss 1967) was applied at each analytical iteration. Theoretical sampling was applied at both the group level, i.e. in evaluating additional data sets to be added, and at the level of individual 'data slices' based on the emergent theory (Glaser 1992).

At the data set level, each data source included in the multi-method research design was selected based on their relevance for developing theoretical concepts. For example, the initial document and interview studies lead to a need for field observations at specific branches and support locations that were specifically salient to creating a deeper understanding of initial narrow concepts and develop these concepts into tentative theory. This step in turn created the need for a deeper understanding of the micro-level dynamics in multiple distributed contexts why digital trace data was sampled.

In the same way, data slices within each data set were sampled to empirically refine and validate the emerging concepts. This was the case in all the data sets collected including document requests, interviewee selection, observation site selection and in the slicing of digital trace data.

In order to assure that the analysis provided sufficient level of abstraction, the coding was ‘scaled up’ to involve only one or two core categories (Glaser 1978, 1992). In the context of this research the specific core categories applied was that of ‘micro-level’ and ‘organisation-level’ concepts. This helped in reducing conceptual complexity in backgrounding less important layers of abstraction and to refine the understanding of the emerging theory. This practice also served to ensure that the theory generated would be relatable to existing theory of distributed digital innovation.

Finally, the emerging substantive theory was integrated into existing theory. This is achieved through relating the emerging theory to other theories in the same or similar field. In this research, such integration is represented in the discussion and theory building chapter (chapter 6), and leads to the generation of a tentative formal theory in the form of the mechanism of double-cumulative synthesis. Specifically, emerging concepts were compared to the existing literature on distributed agency in technological innovation, mainly in the form of path creation theory (Garud and Karnøe 2003) and Usher’s (1955) theory of cumulative synthesis as well as distributed digital innovation (Boland et al. 2007; Yoo et al. 2010), to integrate the emerging tentative theory with existing literature.

The critique can be suggested that the tentative theory generated in this research provides a high-level explanation of a mechanism that can be found in any innovation process even in the absence of digital technology. In response to such critique, and to establish the scope and limits of the theory generated, I would like to point to the multiple elements of this mechanism that directly or indirectly relies on digitalisation including digital infrastructure for connecting geographically and organisationally distributed micro-level actions, the nature of digitally emergent actants participating in the innovation network, and the nature of agency dynamics enacted by human and digital actants connected through a digital infrastructure.

Because of the grounded research approach and the empirical nature of the components of the proposed theory, the scope of the double-cumulative synthesis mechanism, being a tentative theory of agency dynamics in distributed innovation, is limited to the scope of innovation processes that include elements of digital distribution.

8.4 Future Research

As proposed in previous sections of this concluding chapter, the tentative theory presented in this thesis applies to the generalised context of distributed digital innovation. However, the empirical data collected for this research provide the opportunity for much more granular descriptions of specific distributed interactions and richer descriptions of the actants involved. When evaluating the qualitative nature of this research, it is apparent that more research efforts could be directed at providing thick descriptions to increase the communicative validity and inspire greater confidence in its findings.

Future research could also be concerned with widening the scope of the proposed theory. It would be interesting to test the theory of double-cumulative synthesis in other comparable organisational contexts such as Santander or

NatWest. Also, the theory could be tested against financial service providers in other geographical and cultural locations as well as other retail service providers such as real estate agents or insurance brokers. In order to test the theory of double-cumulative synthesis in other empirical contexts, it would be especially useful to further explore three areas related to this research; a) the nature of digitally distributed small-scale actions that emerge into radical organisational transformations, b) the properties, structure and dynamics of innovation networks and c) the role of management and leadership in orchestrating distributed digital innovation. Table 16 provides an overview possible research questions and related testable propositions to guide future research seeking to test the theory in the scope of the empirical contexts mentioned above.

Table 16. Venues for Future Research

Future research questions	Proposed testable propositions based on findings
Qa: What is the nature of digitally distributed small-scale interactions that affect organisational transformation?	P1: Digitally distributed small-scale actions affect radical organisational transformations P2: Effective small-scale interactions include proposition, opposition and synthesis
Qb: What is the process by which transformations are shaped by and disseminate through digital innovation networks?	P3: The effectiveness of distributed actions is contingent upon the nature of interactions P4: Transformations travel through innovation networks by way of a series of local adaptations P5: Organisational transformations emerge from patterns of small-scale adaptations that form new connections within the innovation network
Qc: What is the role of management and leadership in orchestrating distributed digital innovation?	P6: Social network analysis and computational content analysis provide a set of metrics that can be used to monitor and manage distributed digital innovation P7: Technology focus, relational management and organisational structuring are key leadership skills in distributed digital innovation

Finally, the methodological framework presented in this thesis as grounded computational analysis is still in many respects embryonic and thus in need of further research efforts to mature. On the empirical level, further implementations of the grounded computational analysis framework in empirical research are needed to validate its relevance and usefulness beyond the scope of this thesis. On the conceptual level, the sequence of data science imported for the purpose is in need of further thick description including empirically studying the practices of data scientists to refine the understanding of each element in the process.

In summary, this research opens at least three different, yet inter-related, streams of future research including more in-depth empirical research on the digital transformation of organisations through distributed digital innovation, conceptualising decision-making and agency of algorithms and digitally emergent actors, and further development of grounded computational analysis in information systems and management research.

8.5 Final Summary

As this thesis is about to conclude, it is time to summarise the research as presented in the eight preceding chapters. The thesis opened with a description of my motivations for pursuing an academic career and specifically for embarking on the specific research project presented here as part of my Ph.D.

The introduction presented the scope of the thesis and formulated the research questions derived from the overarching question of how do digitally distributed actions lead to radical organisational transformation. It then specified the research objectives, approach and contribution targets of the thesis before presenting the structure of the thesis.

The literature review first conceptualised the dimensions in which digital innovation is distributed, i.e. technology, knowledge and organisational control dimensions. From this vantage point, it reviewed conceptualisations of organisational transformation, micro-level actions in technological innovation and innovation networks in existing research.

Following from this the 'grounded computational analysis' research approach was developed and exemplified in chapter 3 before being applied to construct a mixed-methods research design. The research design was structured in three iterations relating to analysing the process of digitally enabled organisational transformation, the distribution of innovation activities in networks of heterogeneous actors, and the characteristics and dynamics of micro-level actions respectively.

This research design was then applied in the empirical analysis of a radical transformation of frontline customer service in retail banking at Barclays. Following the analysis, findings were discussed and related to existing innovation theory to generate a grounded process theory of agency dynamics in distributed digital innovation.

This resulted in the proposition of a theory of 'double-cumulative synthesis' aimed at addressing each of the research questions. The applicability of the theory to other contexts was then discussed before addressing the methodological implications of the grounded computational analysis method and the theory of double-cumulative synthesis.

Finally, this concluding chapter discussed the potential contributions to theory, method and practice of this thesis, before evaluating its validity and limitations and pointing to potential venues of future research that emerged from the work undertaken in the course of my pursuit of this research.

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APPENDIX 1: PAPER ABSTRACTS

This appendix contains abstracts of research papers generated on the basis of the research presented in this thesis.

Appendix 1.1. MIS Quarterly

Andersen, J.V., Henfridsson, O. & Baptista, J., Under Review, Micro-shifts in Distributed Digital Innovation: The Radical Transformation of Retail Banking at GlobalBank, MIS Quarterly.

Abstract

The transformative power of digital technology in organizational settings is widely recognized in the digital innovation literature. One common assumption is that digital transformation involves a distributed innovation process. Prior literature offers powerful views on such distributed innovation with emphases on artifacts, cognition, and control respectively. However, examining the distributed yet radical transformation of GlobalBank's retail banking network we discovered the need for more pointed theoretical tools for capturing the myriad of distributed contributions that make up digitally-enabled transformation. In particular, it is important to understand how and under what conditions small-scale contributions lead to radical trajectory change.

To this end, we introduce and apply the notion of micro-shifts to examine the small-scale moves that cumulatively make up digital innovation. Our two-year multi-method study shows that the transformative powers of micro-shifts are contingent upon a) local micro-level networks, b) the configuration of micro-shifts occurring within such contexts, and c) the prior sequence of shifts at the time of

occurrence. We use these findings to build a theoretical perspective with significant implications for theory and practice of distributed digital innovation.

Appendix 1.2. Information Systems Research

Andersen, J.V., Ingram, C., Under Review, Modes of Digital-first Organising: Digital Infrastructure Evolution in the Absence of Organisational Embeddedness. Information Systems Research.

Abstract

Research on digital infrastructure evolution has rested on the assumption that infrastructures are created by social actors to support some organised activity. As a consequence of this ‘organisation-first’ perspective, the conditions and dynamics by which the emergence of digital infrastructure, may lead to organising and social interaction remain unexplored. To cast light on this subject, this paper develops and substantiates the concept of a ‘digital-first’ infrastructure to capture the ways in which organising emerges as a consequence of digital infrastructure evolution.

In order to explore and develop this concept, this paper investigates an extreme case of such digital-first infrastructure: the emergence of the Bitcoin community around a specific instantiation of the Blockchain infrastructure. Our 6-year, longitudinal, multi-method case study examines how such a digital-first infrastructure evolves, and how changes in the code of the infrastructure lead to changes in organising.

The paper contributes with an understanding and theoretical framework of how digital infrastructures can emerge in the absence of a priori organisation. A key theoretical implication is that digital-first infrastructure evolution requires taking

the perspective of the artefact in combining insights from systems development and digital infrastructures literatures.

Appendix 1.3. Journal of Strategic Information Systems

Andersen, J.V., Lindberg, A. & Lindgren, R., Under Review, Explaining How Algorithms Make Decisions: A Theoretical Framework. Journal of Strategic Information Systems.

Abstract

Today's business processes rely increasingly on autonomous decision-making algorithms. Their prevalence puts managers in a predicament because it is often unclear how and why these algorithms make particular decisions. This calls for studies that assess and reframe past conceptualizations of material agency. Indeed, such studies must seek to conceptualize the capacity of algorithms to make decisions without relying on human agency. In this paper, we develop a novel theoretical framework that centers around algorithmic operations tied together in "action nets." As such, it offers a more useful conceptualization of material agency in that it explicates how agency emanates from the operations of the decision-making algorithm itself. The explanatory power of our framework is illustrated by the example of an online loan application process. Our proposed framework paves the way for studies that apply computational techniques, and also helps managers to balance strategic concerns in decision-making. We conclude the paper by articulating these implications for research and practice.

Appendix 1.4. HICSS

Andersen, J.V. et al., 2016. Algorithmic Agency in Information Systems: Research Opportunities for Data Analytics of Digital Traces. In Proceedings of the 49th Annual Hawaii International Conference on System Sciences.

Abstract

The complex networks of today involve algorithms, humans, machines, and tools. As a consequence of their digital and sociotechnical nature, they increasingly exhibit autonomous and intelligent characteristics. This development puts prevailing assumptions about information systems at stake. In this paper, we specifically engage with a radical reframing of past conceptualizations of machine intelligence or agency. Based on our theorizing, we advance and substantiate a novel algorithmic agency perspective that centres around three key characteristics: algorithmic interpretation, data generativity, and input translation. These characteristics pave the way for a new wave of research in information systems. Our proposed research opportunities for data analytics of digital traces address conditions for, features of, and approaches to algorithmic agency.

Appendix 1.5. EGOS

Andersen, J. & Baptista, J., 2014. Digital Innovation as Paradox – Leveraging tensions to reshape organisations. 30th EGOS Colloquium, Milan.

Abstract

This paper draws on information systems (IS) literature to explore the role of paradox and tensions in organisational innovation processes. The paradox literature provides a valuable framework for exploring tensions in innovation between

exploration and exploitation activities. However, the organisational responses to paradox proposed in the literature focus mainly on reconciling tensions and thereby treat paradox as a property of the organisation rather than a driver for dynamic innovation process. This paper addresses this issue and explores the dynamics of paradoxical events in processes of digital innovation. We an approach that embraces tensions and explores controversy as a driver for digital innovation. Our explorative case study of frontline service innovation in a UK bank suggests three mechanisms to leverage paradox in digital innovation: connectivity infrastructure, knowledge exchange, and support networks. By drawing on research from IS and digital innovation our findings aim to inform research on organisational paradox and innovation.

APPENDIX 2: ANALYTICAL SCRIPTS

In order to ensure maximum transparency and rigor of data collection and various digital trace analyses conducted as part of this thesis, this appendix includes all the analytical scripts used in the course of my work on this thesis. For digital access please visit the Github repository at: https://github.com/dotjonas/Digital-Innovation-PhD

Appendix 2.1. Data Slicing

```
## SAVES UNSTRUCTURED TEXT FILE TO DATA TABLE (Python)
import re
import csv
f = open('../post_text.txt')
authors = []
bodies = []
dates = []

# find all the posts in the unstructured data file
posts = re.findall(r"(?s)(?<=[' Report'|'Question Report'|'Poll
Report'|'people like this. ']).+?(?=ago)", f.read())

# for each post extract author, time, content
for p in posts:
  # extract author and clean text from navigation
  index = p.find(':')                    # find next ':'
  author = p[7:index+1]                  # get the string following ':'
  author = author.replace(":", "")
  author = author.replace("\n", "")
  author = author.replace("ago\n", "")
  author = author.replace("LikeCommentFollow-upMoreViewGet LinkComment\nReport
this item for being abusive or offensive.Your name will not be sent along with this
report.Report \n\n Report", "")
  author = author.replace("eCommentFollow-upMoreShareViewGet LinkComment","")
  author = author.replace("eCommentFollow-upMoreViewGet LinkComment", "")
  author = author.replace("Report this item for being abusive or
offensive.Your name will not be sent along with this report.Report", "")
  author = author.replace("  Report", "")
  author = author.replace("RcommentsView less ", "")
  author = author.replace("eCommentFollow-upMoreShareViewGet", "")
```

```
  author = author.replace("e  ", "")
  author = author.replace(" asked a question", "")
  authors.append(author)
  print 'Author: ' + str(author)

  # get body text
  body = p[index+1:len(p)]
  bodies.append(body)
  print 'Body: ' + str(body)

  # get timestamp
  index = p.find('ago  ')
  date = p[0:index+1]
  dates.append(date)
  print 'Date: ' + str(date) + '\n'

# print output to console
print '\n' + 'EXTRACTION REPORT'
print "Total number of posts: " + str(len(posts))
print 'Total number of authors: ' + str(len(authors))
print 'Total number of bodies: ' + str(len(bodies))
print 'Total number of dates: ' + str(len(dates))

# close the source file
f.close()

# write structured data to .csv
with open('../data.csv', 'wb') as f:
    writer = csv.writer(f)
    rows = zip(authours,bodies,dates)

    for row in rows:
         writer.writerow(row)

## READS .CSV AND SAVES EACH TEXT CELL TO A TEXT DOCUMENT

import csv
import re

directory = "../lsadocs/"
txtcol = 6 # set the column holding the text

with open('../data_lsa.csv', 'U') as csvfile:

    reader = csv.reader(csvfile, delimiter=',')
```

```
    included_cols = [txtcol]

    fcount = 0
    txt = []

    for row in reader:
         # read  text from column in .csv
         content = list(row[i] for i in included_cols)
         txt = str(content)
         # add value to files with < 50 characters
         if (len(txt) < 50):
                txt = "123456789"
         else:
         # generate a nice, clean string
                txt = txt.translate(None, '[]@:')
                txt = txt.strip()
                #      txt = txt.translate(None, '[]@:')
                txt = re.sub('\n', '', txt)

         #write to .txt file
         if not os.path.exists(directory):
                os.makedirs(directory)
         f = open("../lsadocs/"+str(fcount)+'.txt', 'w')
         f.write(txt)

         #Close the target file
         f.close()

         # increment fcount
         print "Processed doc #: " + str(fcount)
         fcount = fcount + 1
```

Appendix 2.2. Latent Semantic Analysis

```
## GENERATES SEMANTIC VECTOR SPACE FROM DOCUMENT REPOSITORY
library(SnowballC)
library(lsa)

# assign directory holding your docs
txtdir <- "../lsadocs"

#initialise stopwords
data(stopwords_en)

# create de-noised document-term matrix
```

```
	docterm.matrix <- textmatrix(txtdir, stemming = TRUE, stopwords = 
stopwords_en) # stemming = TRUE

	# apply TF-IDF weighing algorithm
	docterm.weighed <- lw_logtf(docterm.matrix) * gw_idf(docterm.matrix)
	summary(docterm.weighed)
	head(docterm.weighed)

	# create the latent semantic space
	lsa.space <- lsa(docterm.weighed)
	summary(lsa.space)

	# display it as a texmatrixatrix again
	lsa.matrix <- as.textmatrix(lsa.space)
	lsa.matrix # YES! SVD IS NOW COMPUTED!
	dim(lsa.matrix)
	head(rownames(lsa.matrix))

	# calculate the optimal dimensionality
	share <- 0.5                   # 119 dimensions with standard share of 0.5
	k <- min(which(cumsum(lsa.space$sk/sum(lsa.space$sk))>=share))
	print(k)
	lsa.reduced <- lsa(docterm.weighed, dims = k)
	summary(lsa.reduced)
```

Appendix 2.3. Identifying Micro-Level Actions

```
	## IDENTIFIES MICRO-ACTIONS
	## Run LSA.R procedure first to genreate latent semantic space

	# Generate micro-action query vector
	querytext <- read.csv("querylist.csv')
	q <- query(querytext, rownames(lsa.matrix), stemming = TRUE)
	print(q)
	summary(q)

	## extract non-zero terms from search result
	query.matrix <- as.matrix(q)
	# add corresponding values to vector
	query.vector <- names(query.matrix[query.matrix > 0, ])

	## calculate semantically associated terms to micro-actions vector using 
cosine similarity
	library(lsa)
	ms.vector <- ""
	for (i in 1:length(query.vector)){
```

```
            print(query.vector[[i]])
            associations <- associate(lsa.matrix, query.vector[i], measure =
"cosine", threshold = 0.5)
            associations <- associations[associations != ""]
            print(names(associations))
            ms.vector <- c(ms.vector, names(associations))
      }
      ms.vector <- ms.vector[ms.vector != ""]
      summary(ms.vector)

      ## create a reduced micro-action matrix subset by micro shift vector
      ms.space <- lsa.matrix[ms.vector, ] # subset lsa.matrix rows by the micro-
action vector
      # turn it into a textmatrix object
      ms.matrix <- as.matrix(ms.space)
      # show me it worked
      class(ms.matrix)
      dim(ms.matrix)

      ## generate heat map of micro-shifts

      # simplify to monthly means (to shorten time-scale)
      dec12.ms <- rowMeans(ms.matrix[,c(1724:1843,1843)])
      jan13.ms <- rowMeans(ms.matrix[,c(1597:1723,1843)])
      feb13.ms <- rowMeans(ms.matrix[,c(1503:1596,1843)])
      mar13.ms <- rowMeans(ms.matrix[,c(1390:1502,1843)])
      apr13.ms <- rowMeans(ms.matrix[,c(1130:1389,1843)])
      may13.ms <- rowMeans(ms.matrix[,c(1105:1129,1843)])
      jun13.ms <- rowMeans(ms.matrix[,c(955:1104,1843)])
      jul13.ms <- rowMeans(ms.matrix[,c(902:954,1843)])
      aug13.ms <- rowMeans(ms.matrix[,c(851:901,1843)])
      sep13.ms <- rowMeans(ms.matrix[,c(743:850,1843)])
      oct13.ms <- rowMeans(ms.matrix[,c(633:742,1843)])
      nov13.ms <- rowMeans(ms.matrix[,c(568:632,1843)])
      dec13.ms <- rowMeans(ms.matrix[,c(503:567,1843)])
      jan14.ms <- rowMeans(ms.matrix[,c(479:502,1843)])
      feb14.ms <- rowMeans(ms.matrix[,c(366:478,1843)])
      mar14.ms <- rowMeans(ms.matrix[,c(122:365,1843)])
      apr14.ms <- rowMeans(ms.matrix[,c(68:121,1843)])
      may14.ms <- rowMeans(ms.matrix[,c(1:67,1843)])

      hm.month <-
cbind(dec12.ms,jan13.ms,feb13.ms,mar13.ms,apr13.ms,may13.ms,jun13.ms,jul13.ms,aug13.
ms,sep13.ms,oct13.ms,

nov13.ms,dec13.ms,jan14.ms,feb14.ms,mar14.ms,apr14.ms,may14.ms)
      head(hm.month)
```

```
dim(hm.month)
sum(hm.month >= 0)

#Normalise values
normalized = (hm.month-min(hm.month))/(max(hm.month)-min(hm.month))
head(normalized)

#Histogram of raw data and normalized data
par(mfrow=c(1,2))
hist(hm.month,xlab="Data",col="lightblue",main="")
hist(normalized,xlab="Normalized Data",col="lightblue",main="")

#format data
library(reshape2)
hm.scaled <- as.matrix(scale(normalized))
hm <- melt(hm.scaled)

# draw heat map
library(ggplot2)
p <- ggplot(hm, aes(y=Var1,x=Var2))
p + geom_tile(aes(fill=value)) + scale_fill_gradient(low="black",
high="orange") + xlab("TIME") + ylab("CONCEPTS")
```

Appendix 2.4. Cluster Analysis

```
## K-MEANS CLUSTERING OF MICRO-ACTIONS
nc = 10 # number of clusters to test cluster sum of squares
nclust = 4 # number of clusters selected as inout for kmeans algorithm

# Determine optimal number of k-means clusters within group SSE
wss <- (nrow(ms.matrix)-1) * sum(apply(ms.matrix, 2, var))
for (i in 2:nc) {
      wss[i] <- sum(kmeans(ms.matrix, centers = i)$withinss)
}

#plot with ggplot2
library(ggplot2)
n <- as.data.frame(wss)
n$nclust <- 1:nc
n
ggplot(data=n, aes(x=nclust,y=wss)) +
      geom_line(alpha=.3) +
      geom_point(size=3) +
      xlab("Number of Clusters") +
      ylab("Within groups sum of squares") +
```

```
      ggtitle("Cluster sum of squares")

# create dataframe with term, mean.sin.val, total count columns
mean.sin.val <- apply(ms.matrix, 1, mean)
summary(mean.sin.val)
cluster.df <- as.data.frame(mean.sin.val)
sum.sin.val <- apply(ms.matrix,1,sum)
table(sum.sin.val)
cluster.df$sum.sin.val <- factor(sum.sin.val)
head(cluster.df)

# perform k-means clustering with 5 clusters (as determined above)
kclust <- kmeans(cluster.df, nclust) # k cluster solution
kclust
kclust$totss
names <- kclust[kclust$cluster==3]
names

# update data frame with cluster and term columns
cluster.df$cluster = factor(kclust$cluster)
centers = as.data.frame(kclust$centers)
cluster.df$term <- ms.vector
head(centers)
head(cluster.df)

# plot variance
ggplot(data=cluster.df, aes(x=sum.sin.val, y=mean.sin.val)) +
      geom_point() +
      geom_point(data=centers, aes(x=sum.sin.val,y=mean.sin.val,
color='Center')) +
      geom_point(data=centers, aes(x=sum.sin.val,y=mean.sin.val,
color='Center'), size=52, alpha=.3, show.legend = FALSE)

# generate term vectors for each cluster
cluster.terms <- data.frame()
for (i in 1:nclust){
      t <- rownames(subset(cluster.df,cluster.df$cluster==i))
      print(c("Cluster",i,t,"/n"))
      cluster.terms$i <- t
}
cluster.terms
```