THE GENERATIVE MECHANISMS OF DIGITAL INFRASTRUCTURE EVOLUTION

Bendik Bygstad
IFI 15.October 2013
THE GENERATIVE MECHANISMS OF DIGITAL INFRASTRUCTURE EVOLUTION

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The current literature on digital infrastructure offers powerful lenses for conceptualizing the increasingly interconnected information system collectives found in contemporary organizations. However, little attention has been paid to the generative mechanisms of digital infrastructure, that is, the causal powers that explain how and why such infrastructure evolves over time. This is unfortunate, since more knowledge about what drives digital infrastructures would be highly valuable for managers and IT professionals confronted by the complexity of managing them. To this end, this paper adopts a critical realist view for developing a configurational perspective of infrastructure evolution. Our theorizing draws on a multimethod research design comprising an in-depth case study and a case survey. The in-depth case study, conducted at a Scandinavian airline, distinguishes three key mechanisms of digital infrastructure evolution: adoption, innovation, and scaling. The case survey research of 41 cases of digital infrastructure then identifies and analyzes causal paths through which configurations of these mechanisms lead to successful evolution outcomes. The study reported in this paper contributes to the infrastructure literature in two ways. First, we identify three generative mechanisms of digital infrastructure and how they contingently lead to evolution outcomes. Second, we use these mechanisms as a basis for developing a configurational perspective that advances current knowledge about why some digital infrastructures evolve successfully while others do not. In addition, the paper demonstrates and discusses the efficacy of critical realism as a philosophical tradition for developing substantive contributions in the field of information systems.

Keywords: Digital infrastructure, case study, case survey, configuration theory, critical realism, generative mechanism, information infrastructure, multimethod, adoption, innovation, scaling
Research question

• Which mechanisms contingently cause digital infrastructure evolution?

Digital infrastructures (information infrastructures, e-infrastructures)

• Supply chains
• Health
• Telecom
• Social media
• Natural resources
• Government

A mechanism is a causal structure that explains a phenomenon
Case: Norwegian

- Starting in 2002
- Deregulation of air traffic

Today:
- 383 routes to 122 destinations in Europe, Middle East, Thailand og USA.
- 17 mill passengers in 2012
- 3000 employees
- Revenues 1.5 bn US dollar

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Norwegian timeline: SOA

- Establishment of a service oriented architecture (SOA)
- Airline company start

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2002: IT architecture

Norwegian Business API

Norwegian Business Bus

- Amadeus Booking
- Amadeus Inventory
- Amadeus Faring
- Rocade
- BackOffice

Local business

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Norwegian: Internet bookings and tickets – bypassing travel agencies

- Airline company start
- Establishing A service oriented architecture (SOA)
- Internet bookings

2002  2003  2004  2005  2006  2007  2008  2009  2010  2011

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2003: Bar code on tickets

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Norwegian timeline

- Airline company start
- 2002: Establishing a service oriented architecture (SOA)
- 2003: Internet bookings
- 2004: Establishing Low-Price Calendar
- 2005:  
- 2006:  
- 2007:  
- 2008:  
- 2009:  
- 2010:  
- 2011:  

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## 2005: Low Price Calendar

![Low Price Calendar](image)

### Alle destinasjoner - Billige flybilletter fra Oslo-Alle flyplasser

<table>
<thead>
<tr>
<th>Destination</th>
<th>Price</th>
<th>Price</th>
<th>Price</th>
</tr>
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<td>Agadir</td>
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<td>Amsterdam</td>
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</tr>
<tr>
<td>Antalya</td>
<td>389</td>
<td>399</td>
<td>689</td>
</tr>
</tbody>
</table>

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Norwegian timeline

- Airline company start
- Establishing A service oriented architecture (SOA)
- Internet bookings
- Establishing Low-Price Calendar
- Digital customer communication dominating
- Internet bank
- Bank Norwegian

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

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2007: Bank Norwegian

Internet bank
Handles Norwegian’s FFP system
Profits 2012: 165 mill NOK
Norwegian timeline

- Airline company start
- Establishing A service oriented architecture (SOA)
- Internet bookings
- Establishing Low-Price Calendar
- Digital customer communication dominating
- Internet bank
- Mobile portal
- Bank Norwegian
- Call Norwegian

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

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Norwegian timeline

- Airline company start
- Establishing a service oriented architecture (SOA)
- Internet bookings
- Establishing Low-Price Calendar
- Digital customer communication dominating
- Internet bank
- Mobile portal
- Using Facebook in the ash crisis

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

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Ash crisis in 2010

Number of requests for SAS and Norwegian during the ash crisis
Norwegian timeline

- 2002: Airline company start
- 2003: Internet bookings
- 2004: Establishing a service oriented architecture (SOA)
- 2005: Establishing Low-Price Calendar
- 2006: Internet communication dominating
- 2007: Mobile portal
- 2008: Bank Norwegian
- 2009: Call Norwegian
- 2010: In-flight Broadband services
- 2011: Using Facebook in the ash crisis

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Recent developments at Norwegian

• 2012: Largest airplane order: Norwegian purchases 122 fly from Boeing

• 2013: Start of long-haul operations to Thailand and USA
Innovation

Norwegian Business Bus

Customers

Amadeus

Bank.serv.

Mobile.serv.

Inventory

Revenues

Other.serv.

www.Airline

www.Bank

www.Mobile

www.Next.service

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Critical realism as philosophy and method

Philosophy
Middle ground between positivism and interpretivism

Method
Looking for generative mechanisms
Mixed method approach

1. **Case study**: To identify generative mechanisms. One case: Norwegian.

2. **Case survey** (41 cases): To validate a) whether these mechanisms were activated and b) if the same configurations resulted in successful outcomes.
# Research streams

<table>
<thead>
<tr>
<th>Research Streams</th>
<th>Philosophical tradition</th>
<th>Foundational Literature</th>
<th>Definition (of DI evolution)</th>
<th>Example References</th>
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<tbody>
<tr>
<td></td>
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<td>Holland (1995)</td>
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<td>Mol and Law (2002)</td>
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<td>Urry (2003)</td>
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<td>Callon (1986)</td>
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<td>Latour (1987)</td>
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<td>Engeström (1990)</td>
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<td>Lave and Wenger (1992)</td>
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<tr>
<td>Strategic Asset</td>
<td>Positivist</td>
<td>Strategic choice theory</td>
<td>The process by which managers initiate and implement changes in an organization’s portfolio of systems and tools for increasing the alignment between its IT resources and strategic imperatives.</td>
<td>Broadbent and Weill (1997) Broadbent et al. (1999)</td>
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<td>Beckert (1999)</td>
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<td></td>
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<td></td>
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<td>Child (1972, 1997)</td>
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</tbody>
</table>
... a self-reinforcing process by which new products and services are created as infrastructure malleability spawns recombination of resources.
Adoption

Figure 5: The Adoption Mechanism

...a self-reinforcing process by which more users adopt the infrastructure as more resources invested increase the usefulness of the infrastructure.
Scaling

Figure 6: The Scaling Mechanism

...a self-reinforcing process by which an infrastructure expands its reach as it attracts new partners by creating incentives for collaboration

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The Case Survey

• We (a) collected a large sample of digital infrastructure studies from scholarly sources,

• (b) refined the initial sample using inclusion and exclusion criteria (Yin and Heald 1975), and

• (c) coded the cases using the definitions of the mechanisms identified in the in-depth study:
  – Context (Architecture and Control)
  – Actualized/unactualized mechanism
  – Outcome (successful/unsuccessful)
41 Cases coded...

<table>
<thead>
<tr>
<th>No</th>
<th>Case</th>
<th>Contextual conditions</th>
<th>Mechanisms</th>
<th>Outcome</th>
<th>Comb</th>
<th>Reference</th>
</tr>
</thead>
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<tr>
<td></td>
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<td>Arc</td>
<td>Con</td>
<td>A</td>
<td>I</td>
<td>S</td>
</tr>
<tr>
<td>Case</td>
<td>Description</td>
<td>Coded</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>------</td>
<td>-----------------------------------------------------------------------------</td>
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<tr>
<td>10</td>
<td>Environmental Health in the French Public Health Administration: Analyzes a successfully distributed network of practice, 2000 to 2005, supported by an emerging information infrastructure.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>French Rail: Aiming to transfer an airline booking system to a railway context. Fails because of “translation” problems.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Descriptive statistics

Table 6. Descriptive Statistics

<table>
<thead>
<tr>
<th>Mechanism combination</th>
<th>N (%)</th>
<th>Unsuccessful infrastructure</th>
<th>Successful infrastructure</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>11 (26.8%)</td>
<td>11</td>
<td>0</td>
<td>11 (100%)</td>
</tr>
<tr>
<td>A</td>
<td>3 (7.3%)</td>
<td>2</td>
<td>1</td>
<td>3 (100%)</td>
</tr>
<tr>
<td>I</td>
<td>4 (9.7%)</td>
<td>2</td>
<td>2</td>
<td>4 (100%)</td>
</tr>
<tr>
<td>S</td>
<td>1 (2.4%)</td>
<td>1</td>
<td>0</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>AI</td>
<td>3 (7.3%)</td>
<td>1</td>
<td>2</td>
<td>3 (100%)</td>
</tr>
<tr>
<td>AS</td>
<td>7 (17.1%)</td>
<td>0</td>
<td>7</td>
<td>7 (100%)</td>
</tr>
<tr>
<td>IS</td>
<td>0 (0%)</td>
<td>0</td>
<td>0</td>
<td>0 (100%)</td>
</tr>
<tr>
<td>AIS</td>
<td>12 (29.3%)</td>
<td>0</td>
<td>12</td>
<td>12 (100%)</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>41 (100%)</strong></td>
<td><strong>17 (41.5%)</strong></td>
<td><strong>24 (58.5%)</strong></td>
<td><strong>41 (100%)</strong></td>
</tr>
</tbody>
</table>
Successful configurations

Contextual conditions
Loosely-coupled architecture
Decentralized control

Mechanisms
Adoption
Innovation
Scaling

Outcome
Success

Highly successful configurations

AIS
Actualized: 5/12, 1/12, 2/12
Unactualized: 12/12

AS
Actualized: 2/7, 2/7, 3/7
Unactualized: 7/7

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<table>
<thead>
<tr>
<th>Case</th>
<th>Contextual conditions</th>
<th>Mechanisms</th>
<th>Outcome</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>23. Criminal Case Management in Finland: The Criminal Case Management system in Finland was introduced in 1992, and developed into a national integrated infrastructure.</td>
<td>Architecture: Modular, expanded into service oriented architecture. Control: Centralized (but managed by representatives of user institutions)</td>
<td><strong>Innovation</strong>: The Sakari solution helped transforming the whole legal criminal case process, and was extended with new services annually. <strong>Adoption</strong>: Courts, police, prosecutors and prisons were gradually enrolled as new services were integrated. <strong>Scaling</strong>: Linking into other structures was a key strategy.</td>
<td>Sakari was considered a success in Finland. “It is recognised that it has helped make criminal proceedings quicker and more accurate, () and the system has also helped to create a useful exchange of information and practices among the different organizations and actors involved” (p.123).</td>
<td>Fabri (2008)</td>
</tr>
</tbody>
</table>
Conclusions

• Three mechanism explain digital infrastructure evolution: Innovation Adoption, Scaling

• A configurational view
  – The interaction of mechanisms (and contextual conditions) explain outcomes
  – Loose architecture and distributed control are triggers for the AIS configuration, but not for AS

• Critical Realism offers a powerful lens for understanding infrastructure evolution