THE GENERATIVE MECHANISMS OF DIGITAL INFRASTRUCTURE EVOLUTION

Presentation
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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
Digital infrastructures

• What are they?
  – Networks of technology, humans and organisations

• How do they evolve?
  – Through growth
  – Beyond a single actor

• Supply chains
• Health
• Telecom, transport
• Social media
• Government

• Which mechanisms?
• Under which conditions?
Case: Norwegian

• Starting in 2002
• Deregulation of air traffic in Scandinavia and Europe

Today:
• 391 routes to 125 destinations in Europe, Middle East, Thailand og USA.
• 20 mill passengers in 2013
• 3000 employees
• Revenues 2.5 bn Euro (15.5 mrd NOK)

# Key Figures Norwegian

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Operating revenue (MNOK)</td>
<td>15.5</td>
<td>12.8</td>
<td>10.5</td>
<td>8.5</td>
<td>7.3</td>
<td>6.2</td>
<td>4.2</td>
<td>2.9</td>
<td>1.9</td>
<td>1.2</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>Load factor %</td>
<td>78</td>
<td>78</td>
<td>79</td>
<td>77</td>
<td>78</td>
<td>78</td>
<td>80</td>
<td>79</td>
<td>78</td>
<td>67</td>
<td>62</td>
<td>52</td>
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<tr>
<td>Passengers (million)</td>
<td>20.7</td>
<td>17.7</td>
<td>15.7</td>
<td>13.0</td>
<td>10.8</td>
<td>9.1</td>
<td>6.9</td>
<td>5.1</td>
<td>3.2</td>
<td>2.0</td>
<td>1.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Number of routes</td>
<td>391</td>
<td>308</td>
<td>271</td>
<td>249</td>
<td>206</td>
<td>170</td>
<td>114</td>
<td>86</td>
<td>54</td>
<td>43</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Number of aircraft</td>
<td>85</td>
<td>68</td>
<td>62</td>
<td>57</td>
<td>46</td>
<td>40</td>
<td>32</td>
<td>22</td>
<td>14</td>
<td>12</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

Bendik Bygstad, IFI 1.Nov 2013
Norwegian timeline: SOA

- Airline company start
- Establishing A service oriented architecture (SOA)
2003: IT architecture

Norwegian Business API

Norwegian Business Bus

Amadeus Booking
Amadeus Inventory
Amadeus Faring
Rocade
BackOffice

CRM
Amadeus DCS
Data Warehouse

Mobile Internet & Portals
Call center, station travel agent
Narvesen/Retail
Automat
E-mail management
Other WEB channels /API

Local business
Local business
Local business
Local business
Local business
Local business
Local business
Local business
Local business
Local business

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Norwegian: Internet bookings and tickets – bypassing travel agencies

Airline company start

2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

Establishing A service oriented architecture (SOA)

Internet bookings

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2003: Bar code on tickets
Norwegian timeline

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

2005: Low Price Calendar

Alle destinasjoner - Billige flybilletter fra Oslo-Alle flyplasser

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Norwegian timeline

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

- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
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

Norwegian timeline

- Airline company start
  - 2002
  - Establishing A service oriented architecture (SOA)
  - Internet bookings

- Establishing Low-Price Calendar
  - 2005

- Internet bank
  - 2006

- Digital customer communication dominating
  - 2007

- Mobile portal
  - 2008

- Using Facebook in the ash crisis
  - 2009

- Bank Norwegian
  - 2010

- Call Norwegian
  - 2011
Ash crisis in 2010

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

Airline company start

2002

Establishing A service oriented architecture (SOA)

Internet bookings

2003

Establishing Low-Price Calendar

Digital customer communication dominating

2004

Bank Norwegian

Internet bank

2005

Call Norwegian

Mobile portal

2006

Using Facebook in the ash crisis

2007

In-flight Broadband services

2008

2009

2010

2011

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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
Research question

• Which mechanisms contingently cause digital infrastructure evolution?

• A mechanism is a causal structure that explains a phenomenon, such as the market mechanism and the "self-fulfilling prophecy"
Innovation
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.

1. **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>
</tr>
</thead>
<tbody>
<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>
</tr>
</tbody>
</table>
Innovation

... a self-reinforcing process by which new products and services are created as infrastructure malleability spawns recombination of resources.
Adoption

...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.
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>Contextl. conditions</th>
<th>Mechanisms</th>
<th>Outcome</th>
<th>Comb</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Arc</td>
<td>Con</td>
<td>A</td>
<td>I</td>
<td>S</td>
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<tr>
<td>1</td>
<td>Health Information Systems Project</td>
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<td>1</td>
<td>1</td>
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<tr>
<td></td>
<td>HISP: A successful standardization strategy in low-resource countries,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>leading to paralysis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case</td>
<td>Description</td>
<td>Code 1</td>
<td>Code 2</td>
<td>Code 3</td>
<td>Code 4</td>
<td>Code 5</td>
</tr>
<tr>
<td>------</td>
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<tr>
<td>9</td>
<td>Legal systems: An expanding legal infrastructure in Austria, growing organically from 1972.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</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>
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<td>1</td>
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<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>
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</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>
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<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
- 5/12
- 1/12
- 2/12
- 12/12

AS
- 2/7
- 2/7
- 3/7
- 7/7

Actualized  Unactualized
<table>
<thead>
<tr>
<th><strong>Contextual conditions</strong></th>
<th><strong>Mechanisms</strong></th>
<th><strong>Outcome</strong></th>
<th><strong>Reference</strong></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.</td>
<td><strong>Innovation</strong>: The Sakari solution helped transforming the whole legal criminal case process, and was extended with new services annually.</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>
</tr>
</tbody>
</table>
Conclusions

• Three mechanisms 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