THE GENERATIVE MECHANISMS OF DIGITAL INFRASTRUCTURE EVOLUTION

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THE GENERATIVE MECHANISMS OF DIGITAL INFRASTRUCTURE EVOLUTION[1]

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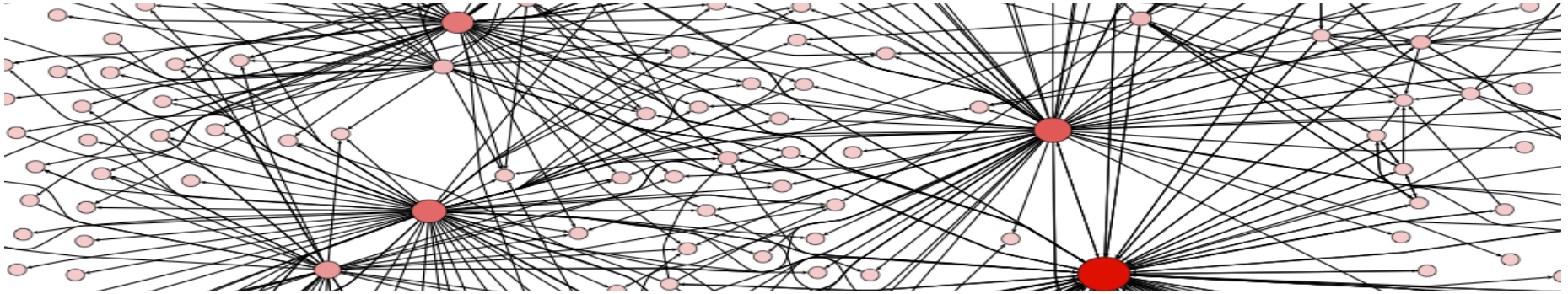
The current literature on digital infrastructure offers powerful lenses for conceptualizing the increasingly interconnected information system collectives found in contemporary organizations. However, little attention has been paid to the generative mechanisms of digital infrastructure, that is, the 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**

- **Supply chains**
- **Health**
- **Telecom, transport**
- **Social media**
- **Government**



- How do they evolve?
  - **Through growth**
  - **Beyond a single actor**

- **Which mechanisms?**
- **Under which conditions?**

Case: Norwegian

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

Bjørn Kjos

Hans-Petter Aanby

Today:

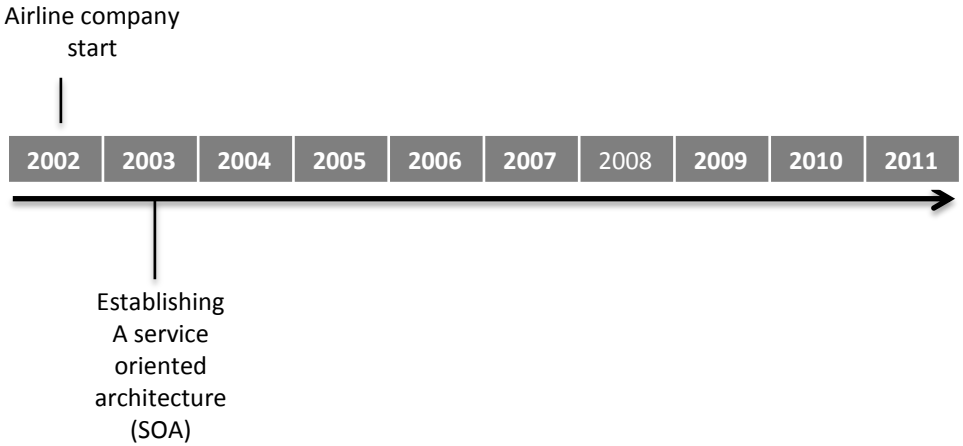
- 391 routes to 125 destinations in Europe, Middle East, Thailand og USA.
- 20 mill passengers in 2013
- 3000 employees
- Revenues 2.5 bn Euro (15.5 mrd NOK)

Bygstad, B. and Aanby, H.P. (2010) "ICT Infrastructure for innovation : A case study of the enterprise service bus approach". *Information Systems Frontiers*, 12(3): 257-265.

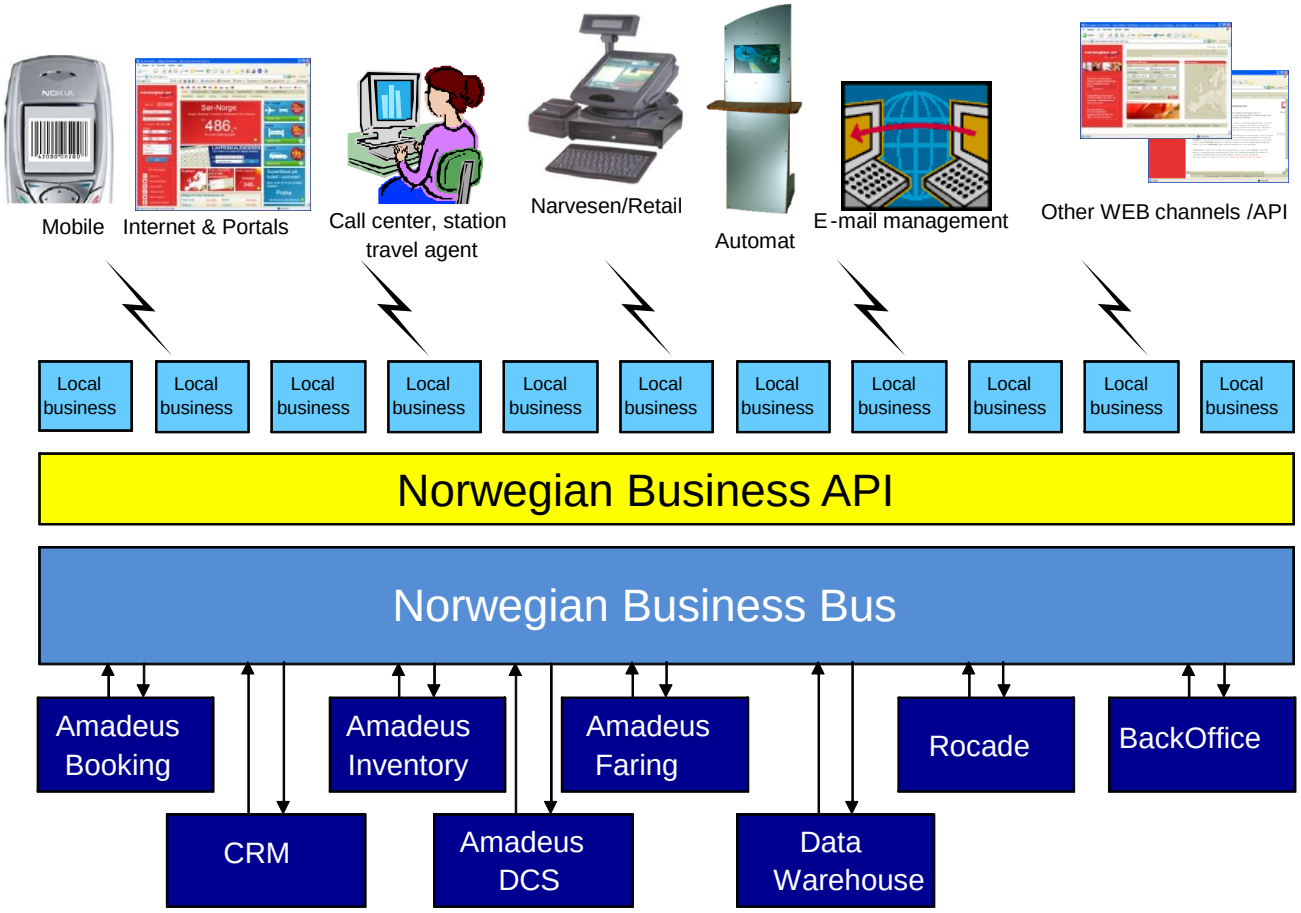
Key Figures Norwegian

	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002
Operating revenue (MNOK)	15,5	12,8	10,5	8,5	7,3	6,2	4,2	2,9	1.9	1.2	0.9	0.3
Load factor %	78	78	79	77	78	78	80	79	78	67	62	52
Passengers (million)	20.7	17.7	15.7	13.0	10.8	9.1	6.9	5.1	3.2	2.0	1.2	0,3
Number of routes	391	308	271	249	206	170	114	86	54	43	18	5
Number of aircraft	85	68	62	57	46	40	32	22	14	12	8	7

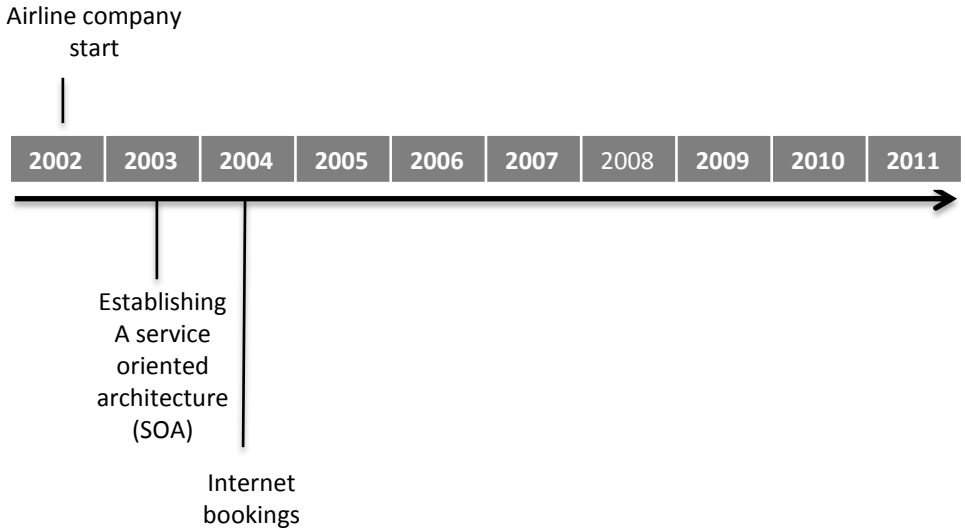
Norwegian timeline: SOA



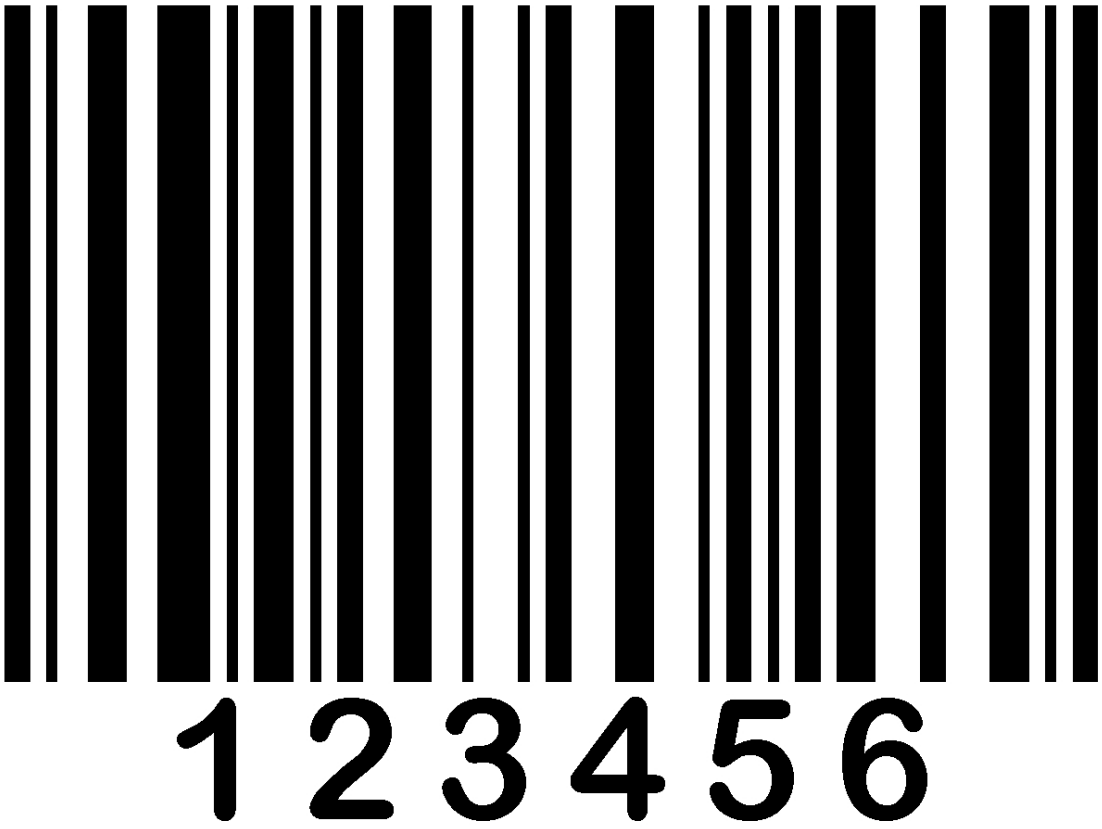
2003: IT architecture



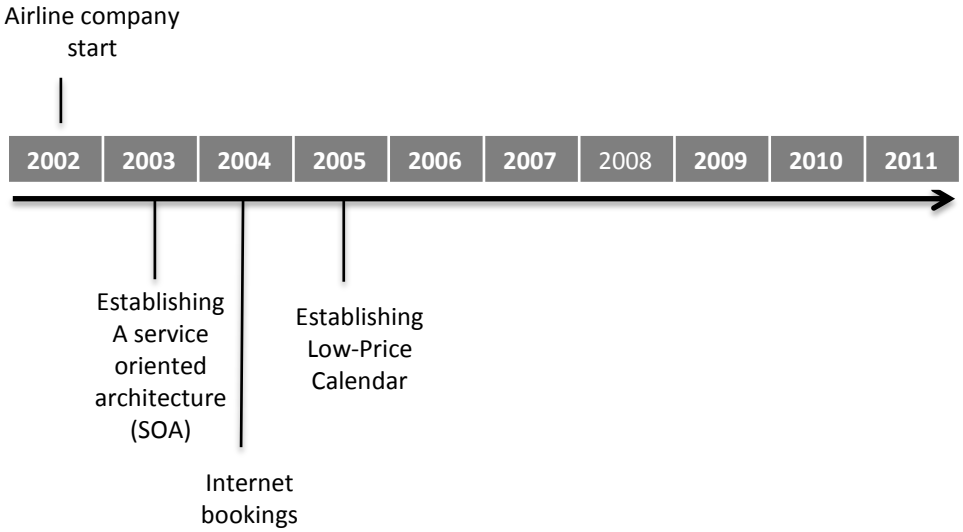
Norwegian: Internet bookings and tickets – bypassing travel agencies



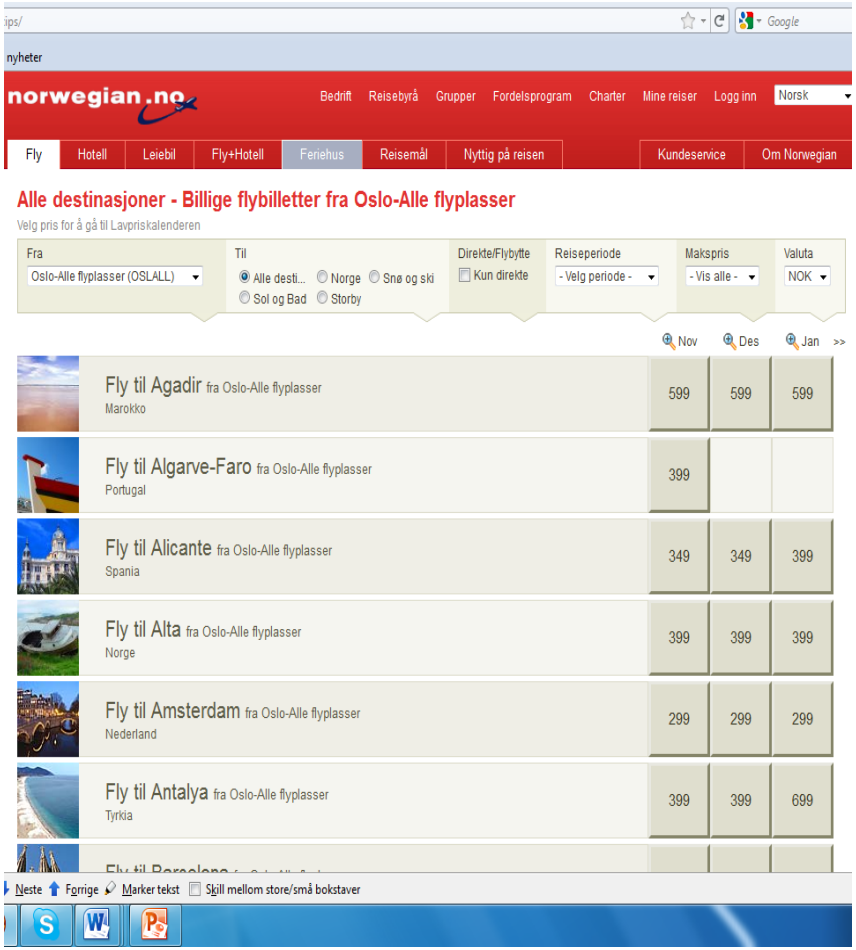
2003: Bar code on tickets



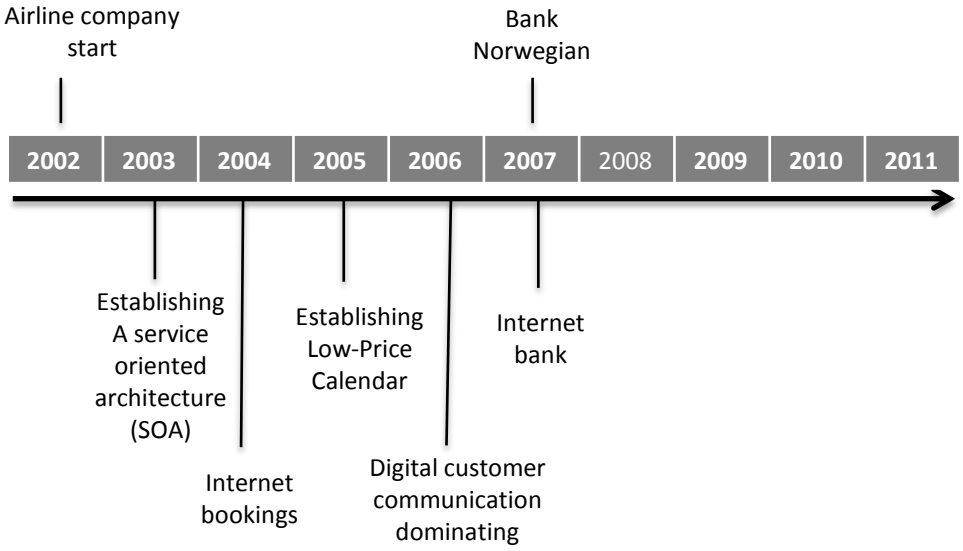
Norwegian timeline



2005: Low Price Calendar



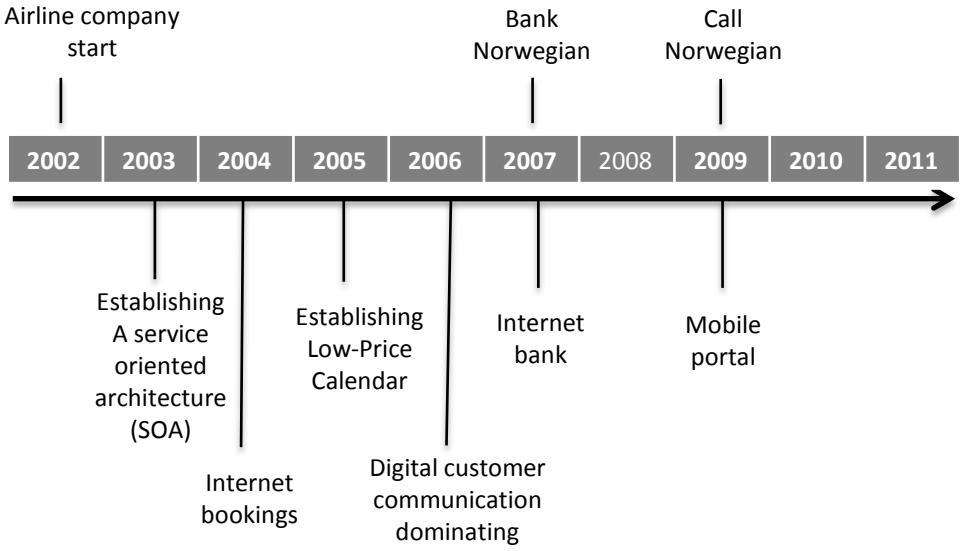
Norwegian timeline



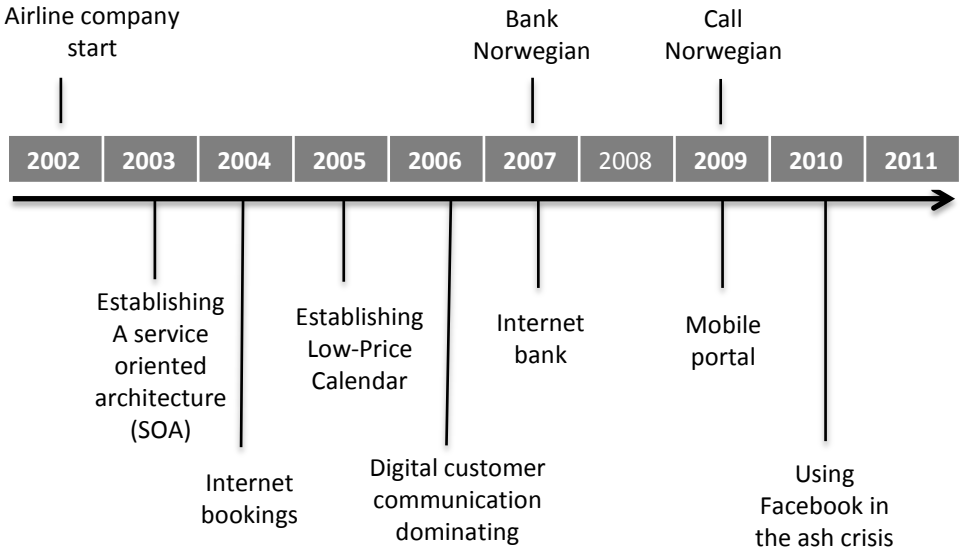
2007: Bank Norwegian

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

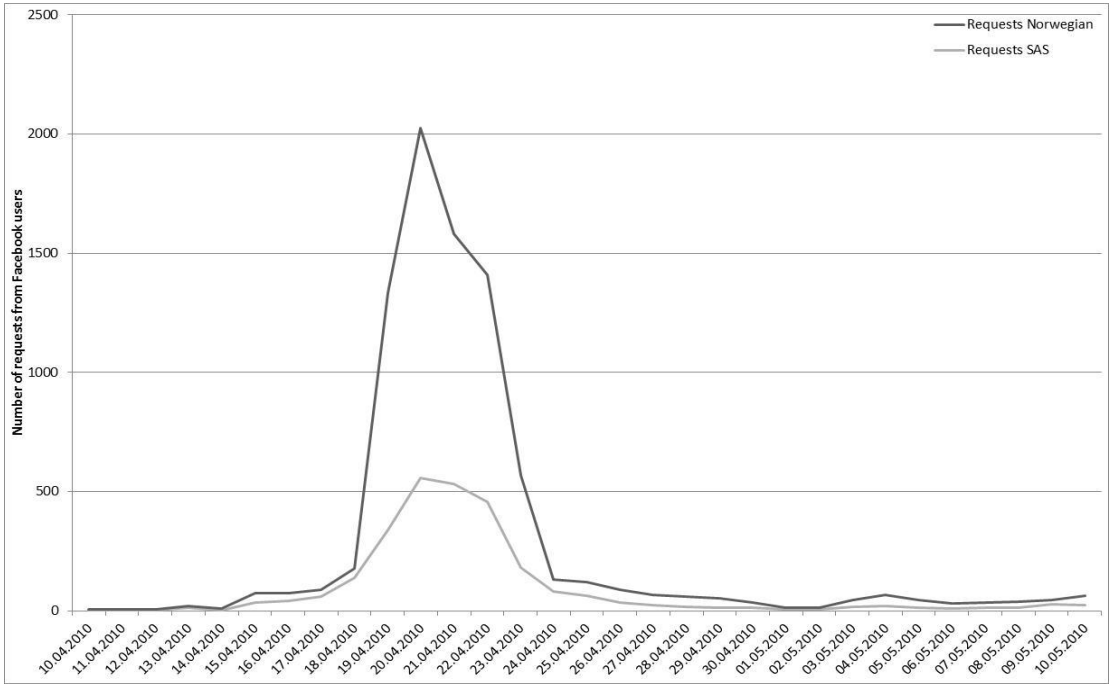
Norwegian timeline



Norwegian timeline

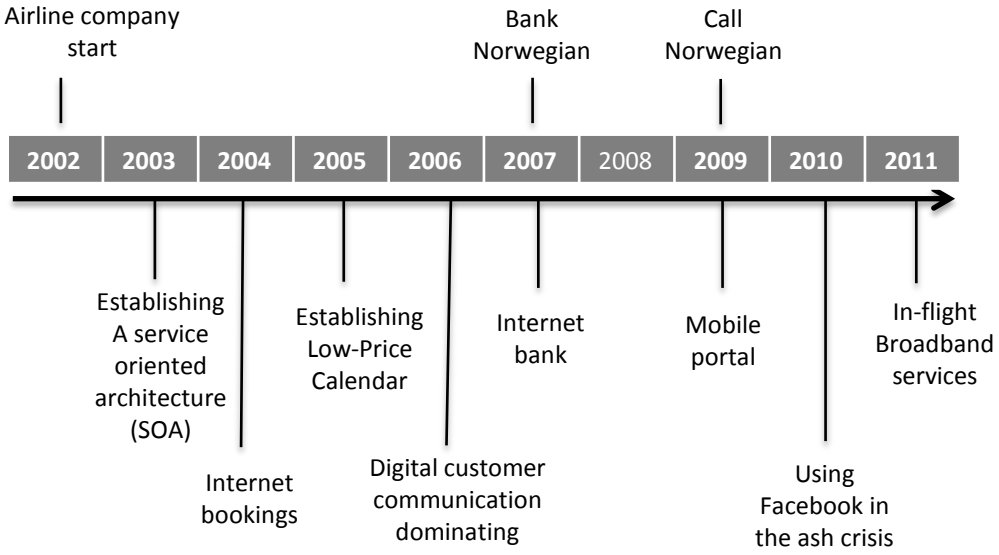


Ash crisis in 2010



Number of requests for SAS and Norwegian during the ash crisis

Norwegian timeline



Recent developments at Norwegian

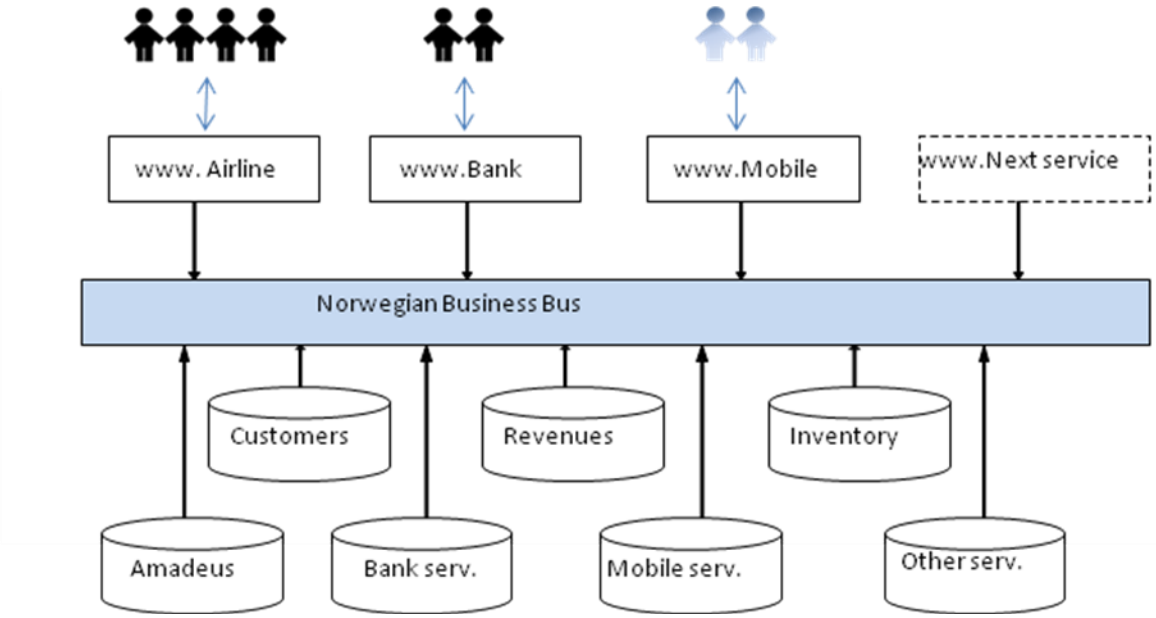
- 2012: Largest airplane order: Norwegian purchases 122 fly from Boeing

- 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 profecy”**

Innovation


www. Airline
www.Bank
www.Mobile
www.Next service
Norwegian Business Bus
Customers
Revenues
Inventory
Amadeus
Bank serv.
Mobile serv.
Other serv.

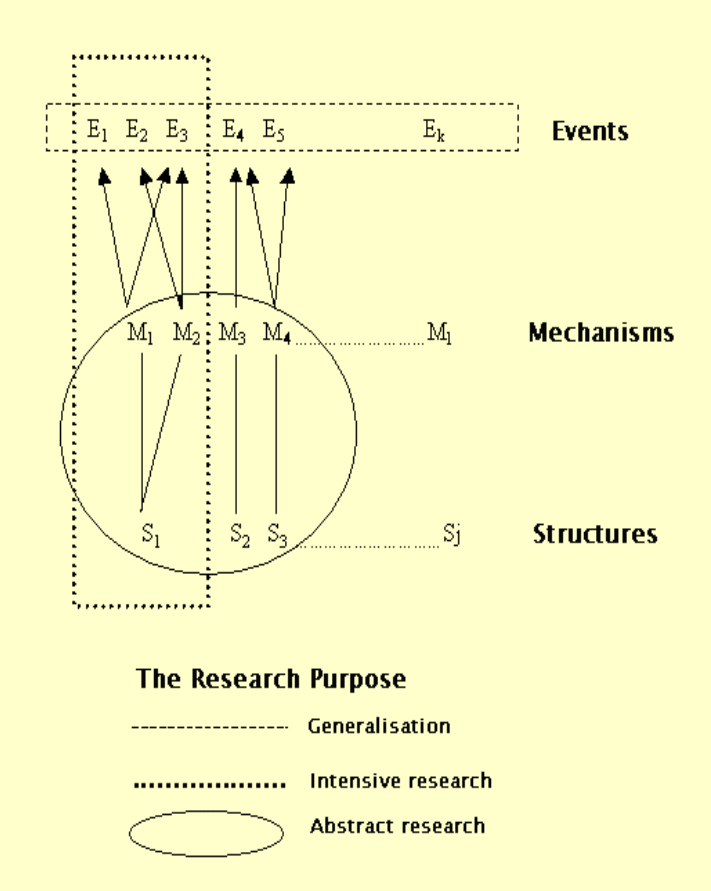
Critical realism as philosophy and method

Philosophy

Middle ground between positivism and interpretivism

Method

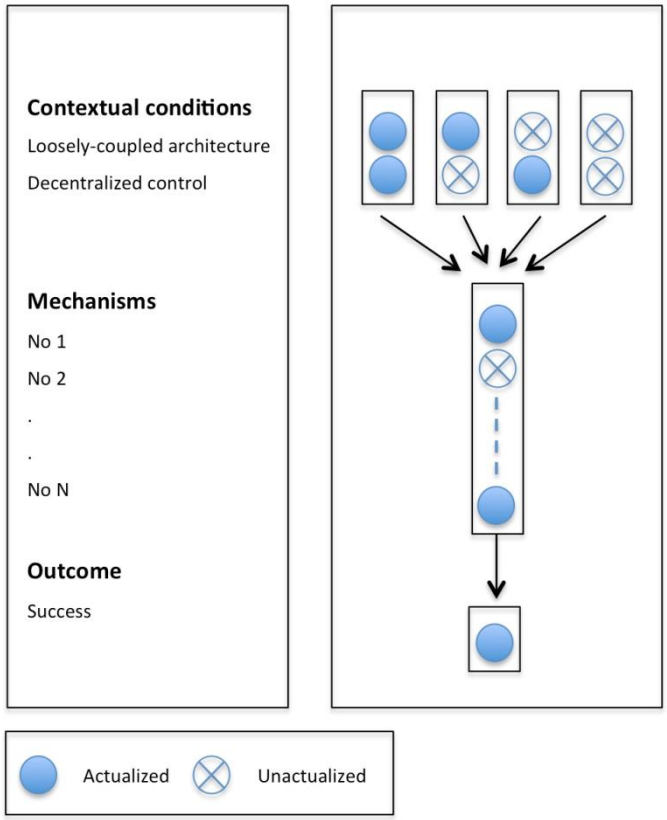
Looking for generative mechanisms



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

Research Streams	Philo-sophical tradition	Foundational Literature	Definition (of DI evolution)	Example References
Comp-lexity	Interpretivist	Complexity theory • Holland (1995) • Mol and Law (2002) • Urry (2003)	The process by which heterogeneous and autonomous human, or organizational, actors seek to use information technology in their adaptation to each other and their external environments.	Braa et al. (2007) Ciborra and Failla (2000) Hanseth et al.(2006)
Network	Interpretivist	Actor-network theory • Callon (1986) • Latour (1987)	The process by which multiple human actors translate and inscribe their interests into a technology, creating an evolving network of human and non-human actors.	Aanestad and Blegind Jensen (2011) Hanseth and Monteiro (1997) Yoo et al. (2005)
Rela-tional	Interpretivist	Work practice and learning theory: • Engeström (1990) • Lave and Wenger (1992)	The process by which socio-technical relations emerge from IT-mediated activities that become meaningful in a given community-of-practice.	Pipek and Wulf (2009) Star and Ruhleder (1996) Vaast and Walsham (2009)
Strategic Asset	Positivist	Strategic choice theory • Beckert (1999) • Child (1972, 1997)	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.	Broadbent and Weill (1997) Broadbent et al. (1999)

Innovation

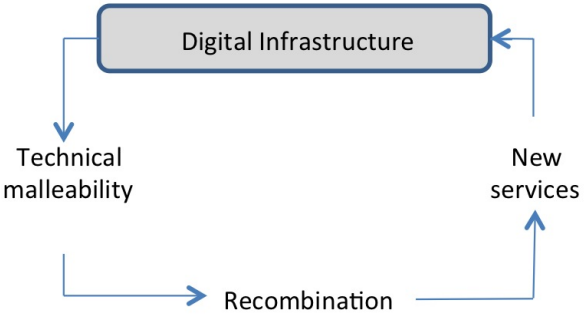


Figure 4: The Innovation Mechanism

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

Adoption

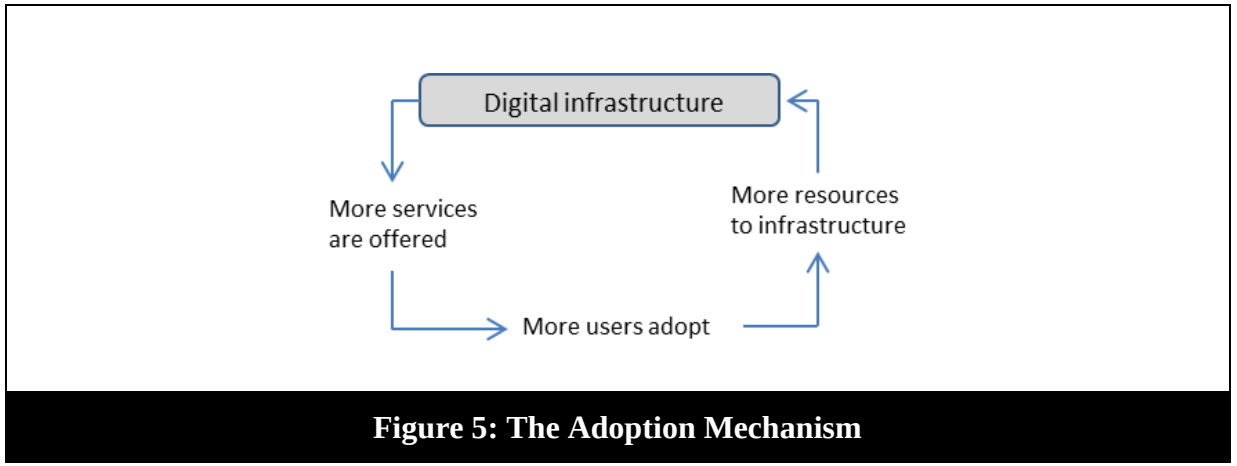


Figure 5: The Adoption Mechanism

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

Scaling

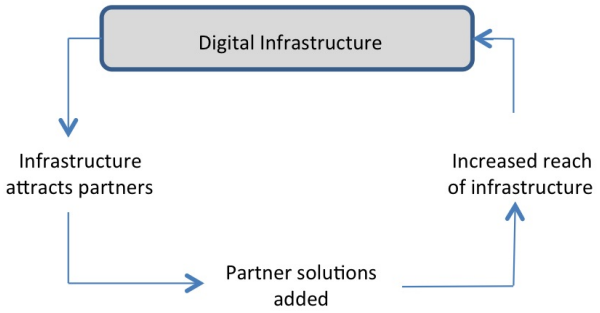


Figure 6: The Scaling Mechanism

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

The Case Survey

- We (a) collected a large sample of digital infrastructurestudies 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 identifid in the in-depth study:
  - Context (Architecture and Control)
  - Actualized/unactualized mechanism
  - Outcome (successful/unsuccessful)

41 Cases coded...

Contextual conditions
Architecture: tightly-coupled (0), loosely-coupled (1)
Control: centralized (0) decentralized (1)
Mechanisms
Adoption (A): Unactualized (0), actualized (1)
Innovation (I): Unactualized (0), actualized (1)
Scaling (S): Unactualized (0), actualized (1)
Outcome: Unsuccessful (0), successful (1)
Comb: Combination of mechanisms

No	Case	Contextl. conditions		Mechanisms			Out-come	Comb	Reference
		Arc	Con	A	I	S			
1	Health Information Systems Project HISP: A successful standardization strategy in low-resource countries, based on flexible and simple solutions. Continuously from 1992-2007.	1	1	1	0	1	1	AS	Braa, J., Hanseth, O., Heywood, A., Mohammed, W., and Shaw, V. 2007. "Developing Health Information Systems in Developing Countries: The Flexible Standards Strategy," MIS Quarterly 31:2, pp 381-402.
2	National Hospital: A case of increasing complexity of requirements, leading to paralysis.	0	0	0	0	0	0	-	Hanseth, O., Jacucci, E., Grisot, M., and Aanestad, M. 2006. "Reflexive Standardization: Side Effects and Complexity in Standard Making." MIS Quarterly, 302, pp.563-581.

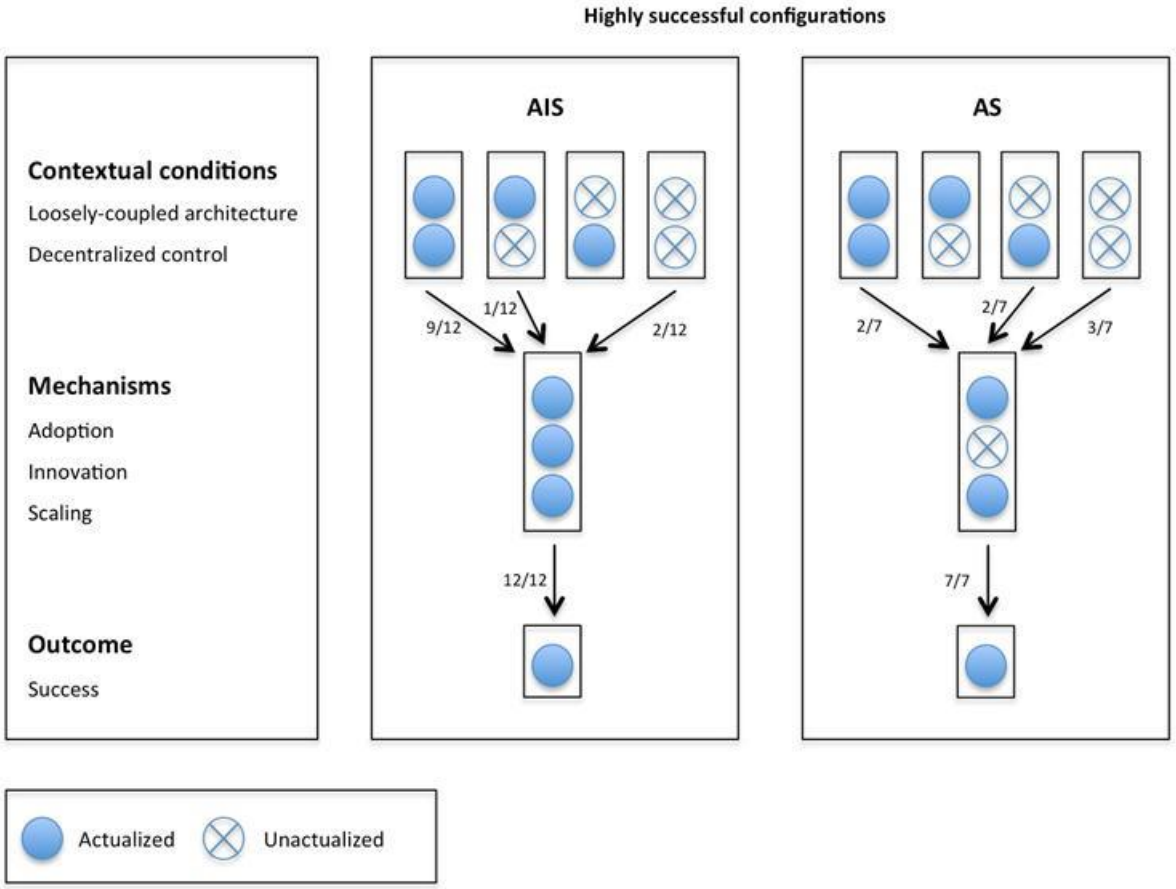
More cases coded

9	**Legal systems: An expanding legal infrastructure in Austria, growing organically from 1972.**	**0**	**0**	**1**	**0**	**1**	**1**	**AS**	**Koch, S. and Bernroider, E. 2008. "Aligning ICT and legal frameworks in Austria's e-bureaucracy: from mainframe to the Inter-net." In Contini and Lanzara eds. ICT and Innovation in the Public Sector European Studies in the Making of E-Government. Palgrave Macmillan, pp. 147-173.**
10	Environmental Health in the French Public Health Administration: Analyzes a successfully distributed network of practice, 2000 to 2005, supported by an emerging information infrastructure.	1	1	1	1	1	1	AIS	Vaast, E. and Walsham, G. 2009 "Trans-situated learning: supporting a network of practice with an information infrastructure." Information Systems Research, 20(4), pp.547-564
11	French Rail: Aiming to transfer an airline booking system to a railway context. Fails because of "translation" problems.	0	0	0	0	0	0	-	Mitev, N. 2000 "Toward Social Constructionist Understandings of IS Success and Failure: Introducing a New Computerized Reservation System," in proceedings of the International Conference of Information Systems, Brisbane, Australia, pp. 84-93.

Descriptive statistics

Table 6. Descriptive Statistics				
Mechanism combination	**N (%)**	**Unsuccessful infrastructure**	**Successful infrastructure**	**Total**
NONE	11 (26.8%)	11	0	**11 (100%)**
A	3 (7.3%)	2	1	**3 (100%)**
I	4 (9.7%)	2	2	**4 (100%)**
S	1 (2.4%)	1	0	**1 (100%)**
AI	3 (7.3%)	1	2	**3 (100%)**
AS	7 (17.1%)	0	7	**7 (100%)**
IS	0 (0%)	0	0	**0 (100%)**
AIS	12 (29.3%)	0	12	**12 (100%)**
Total:	**41 (100%)**	**17 (41.5%)**	**24 (58.5%)**	

Successful configurations



Example

	Contextual conditions	Mechanisms	Outcome	Reference
23. Criminal Case Management in Finland: The Criminal Case Management system in Finland was introduced in 1992, and developed into a national integrated infrastructure.	Architecture: Modular, expanded into service oriented architecture. Control: Centralized (but managed by representatives of user institutions)	**Innovation**: The Sakari solution helped transforming the whole legal criminal case process, and was extended with new services annually. **Adoption**: Courts, police, prosecutors and prisons were gradually enrolled as new services were integrated. **Scaling**: Linking into other structures was a key strategy.	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).	Fabri (2008)

Conclusions

- Three mechanism explain digital infrastructure evolution: **Innovation Adoption, Scaling**
- A configurational view
  - The **interaction** of mechanims (and contextual conditions) explain outcomes
  - Loose architecture and distributed control are triggers for the AIS configuration, but not for AS