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Exploring Enterprise Transformation from a Path Dependence Perspective: A Recycling Case and Conceptual Model

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Abstract. In dispersed, multinational enterprises, complex integrations of information systems are a commonly hated threat as they render difficult fundamental changes of IT structures and standards embedded therein. This paper explores how integrations can turn into a burden and how thereby a company's technology platform can lock-in to a local optimum. We conceptualize information system architectures – a company's set of information systems and integrations – as networks. Based thereupon, we suggest a network model of path building that formalizes architectural growth processes and on-top technology adoptions, as when new systems attach preferentially to important hubs. Agent-based simulations give insights into how different growth parameters, i.e. new systems' degree of integration and preferentiality, increase the architecture's complexity and can reinforce predominant architectural patterns, such as "islands of shared technologies". We contrast the simulation results to empirical data that show the emergence of a fragmented IT landscape in a regionally-dispersed recycling company.

Keywords: EA Modeling and Simulation, Network Analysis, Enterprise Transformation, Path Dependence, EA Visualization

1 The Problem of Path Dependence in IS Architectures

In growing enterprises, numerous, close, and diverse integrations of information systems (IS) can result in 'rigidity traps' where fundamental changes of IS structures and standards embedded therein become increasingly expensive or even impossible [1–4]. One example is multiple co-existing enterprise systems that we observed at a recycling company. The regionally dispersed firm with some East European branches aimed at consolidating overlapping "technological islands" but was drawn back by many integrated add-ons and apps that were hard to map, assess, and eventually replace. Similar challenges exist in other industries such as financial services [5] or retailing [6] where embedded legacy ecosystems create significant change barriers.

In this article, we build on the notion of path dependence as an explanatory for the challenging nature of enterprise transformations (e.g., due diligence for mergers and acquisitions, outsourcing, cost-cutting projects). Our aim, which is first and foremost

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theoretical, is to examine IS architectural networks – a firm's set of IT systems and integrations, or application landscape [7] – and how their growth invokes path building (i.e. increasing change complexity, technological lock-ins). We work toward our objective by drawing on a model of path dependence by Arthur [8] and melding it with a network formation model by Jackson and Rogers [9].

While we build on the notion of path dependence, we also extend it in an important respect. As IS architectures differ significantly from market-based settings, it is necessary to go beyond traditional notions of network effects – increasing returns from growing network sizes – and to take into account local spillovers and domino effects within a dynamic graph that forms the IS architecture at different points in time. Consistent with this view, in what follows, we develop an IS architecture network model of path building that jointly takes into account strategic complementarities and growth processes. We use the term *strategic complementarities* to refer to technological spillovers in an architectural network, as when a SAP CRM is selected as a new system as a consequence of an earlier SAP adoption decision. By *growth*, we refer to processes in which new IT systems entering an architectural network will not integrate fully with all other systems, as when a new controlling app links only to an important ERP cluster. We turn our attention exclusively to growth processes where nodes are born and linked to existing nodes. Following [7], this describes transformative events in which new IT systems are augmented and integrated with the architecture.

Consistent with [10] and [11], we believe that inertia is often the unintended consequence an IS architecture that grows highly independent from central control. We thus turn to an agent-based simulation approach devoting particular attention to emergent outcomes of incremental IS architectural growth.

Our contribution is structured as follows: sec. 2 introduces theoretical antecedents and scientific questions. Sec. 3 derives empirical requirements from an exploratory recycling case and thereupon suggests a conceptual model to understand better how enterprise transformations are inhibited by tendencies of IS architectures towards inertia. Sec. 4 contrasts findings from simulations with empirical data on the recycling company's fragmented IT landscape. Sec. 5 concludes and discusses future directions.

2 Theoretical Foundation, Previous Work, and Research Gap

We discuss path dependence in IS architectures from a network perspective, we point to the research gap and introduce an agent-based simulation as our research approach.

2.1 Organizational IS Architectures as Networks

As our starting point, we draw on previous work that has shown that IS architectures can be usefully visualized and analyzed as networks [7, 12, 13]. Network models enable novel insights into enterprise architecture (EA) topics such as the patterns of shadow IT usage in a company [12] or failure propagation in IT landscapes [14]. Thereby, network models allow examining effects of interdependencies between individual elements, e.g. IT systems, in contrast to aggregated patterns of occurrence, as typically suggested by EA approaches (e.g. absolute number or coverage of SAP applications in a company). Within IS architecture networks, IT systems – e.g., an SAP financial accounting application or an MS Access database for customer data management – can be understood as nodes and edges materialize in specific technical or business integrations. Thus, an edge can mean information flowing through a transferred file, a remote procedure call or any other sort of interface.

Following suit, we conceptualize the technology platform as an attribute (feature, property) associated with the nodes in the IS architecture. Think of a financial accounting application as a node that is based on an 'SAP' platform, its property. Consistent with [15–17], we assume that "on-top" adoption of technology platforms is primarily guided by positive network influences. Along with [15], we denote such tendencies to adopt well-fitting solutions among individual nodes in IS architecture networks as a *strategic complementarity*.

2.2 Growth of IS Architecture Networks as Path Building

We turn to observed tendencies of IS architectures towards inertia. Inertia comes in two flavors: firstly, changes within a grown IS architecture often become complex as applications are cobbled together in numerous, diverse, and close ways [7, 29–31]. Secondly, technologies and standards, basic building blocks of applications and integrations, become often deeply embedded in the architecture, making the emerging architecture a "sunk and sticky investment" [32, 33]. Both pitfalls affect the innovative capability of a company and hinder the transformation of enterprises.

This points to classical problems of path dependence [8, 18, 19]. How can local optima (standards, technologies, platforms) lock-in? The answer is through self-reinforcing mechanisms. Referring to early work on path dependence, four generic sources of self-reinforcement have been outlined [20]: large setup costs, learning effects, coordination effects, and adaptive expectations. In IS architectures, network effects combine them and unleash positive feedback in which "the benefits of owning a product, or using a standard, or, in fact, taking any action, increase [...] with the number of people doing the same thing" [21]. A larger installed base (number of users in a company, departments, or subsidiaries) attracts more complements and services, makes the dominant technology more credible, and thus attracts further adoptions [10]. This is the classical notion of network effects.

Brian Arthur formalized this observation in his classical portrayal of a path-dependent process [8]. Network effect models take the form of $U = a + bN$ where an agent's (e.g., firm, department, individual, or any other entity) utility U to select a technology is a function of its standalone utility a, a network multiplier b and the network size N [22]. Accordingly, the model can be written as a growing network where new agents (nodes) enter sequentially over time ($agent_1$, $agent_2$, and so forth). They form links to all existing agents in the network as they are influenced by N – the entire network size. The more adopters already exist, the larger the likelihood of the same technology being selected in the future [23]. Hence, network influences grow linear with increasing network sizes.

2.3 Research Gap

Previous work on enterprise transformations has primarily focused on building an EA planning capability to *manage* the architectural *evolution* effectively [2, 24–26]. This view assumes that *evolution equals planning.* Equating planning and evolution, however, underemphasizes how transformation initiatives can be undermined by unintended consequences of highly-emergent, bottom-up changes of the architecture [27], i.e. workarounds, business user add-ons, and shadow IT systems.

To the limited extend that work on enterprise transformations has covered unplanned and incremental changes [11, 28], theorizing remains partial and largely anecdotal. To allow for a more nuanced portrayal of how inertia builds up, we thus see a need to complement existing approaches by a perspective of IS architectures as growing networks exposed to path dependence. Thereby, the notion of path dependence offers a simple account of inertia - how one technology or standard can lock in – in settings where incentives to select a solution exhibit positive feedback. However, the traditional notion of path dependence overgeneralizes outcomes of path building processes ("winner-take-it-all") while ignoring the underlying network structure [22, 29]. In contrast, existing work on "hidden structures" suggest that IS architecture tend towards clustering and primarily form core-periphery structures [14, 30]. We thus see the need for a more powerful IS architecture network model of path dependence covering a larger set of growth logics. In summary, we thus ask:

How will an architectural network's growth logic affect path building?

2.4 Agent-Based Simulation as Research Approach

We turn to an agent-based simulation approach as a means for theory building that is useful in complex settings with many actors, nonlinear interactions and long-ranged horizons [31]. Fig. 1 shows our research design and how it relates to different sections of this article. Starting with a definition of the "target", we collected empirical requirements and reconciled them with existing theories and models ("abstraction"). Based thereupon, we specified a conceptual "model" (sec. 3.2).

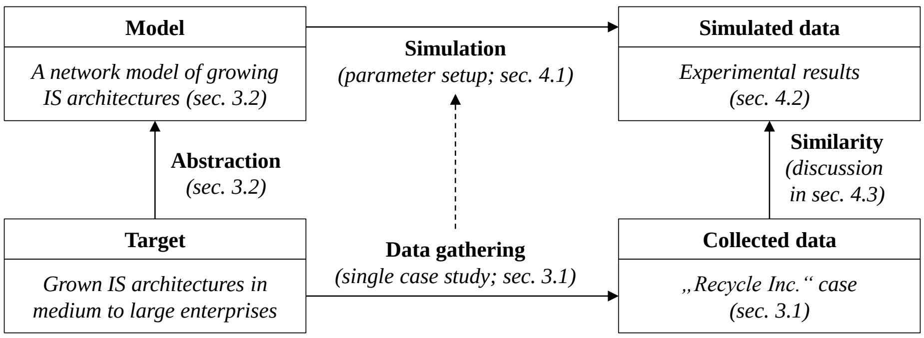

Fig. 1. Research design (adapted from [31])

The model was implemented in an agent-based simulation environment. It was verified and validated (e.g. by replicating Arthur's path dependence model as a special case). Finally, we produced "simulation data" by performing experiments in a virtual laboratory (sec. 4.2). We eventually discuss results against the backdrop of data gathered on the problem instance of a German recycling company ("Recycle Inc.").

3 Recycle Inc. Case and Conceptual Model

We begin by turning our attention to the case site of Recycle Inc. Founded in 1968, the company is a representative example for our target, medium to large enterprise with organically grown IT landscapes. The case is also supportive for our main argument that incremental growth invokes inertia, as within the time of our observation, the company had started an initiative to consolidate its IT landscape in one business domain – waste operations – our unit for our analysis, but was drawn back by the complex characteristics of its grown IS architecture.

3.1 Recycle Inc. as an Example for a Grown IS Architecture

To begin, consider a typical waste management process. As shown in Fig. 2, the process consists of three straightforward activities: distribution (i_1), operations (i_2) and invoicing (i_3). Firstly, one needs to price and sell waste operations services such as containers of different qualities (i_1). Secondly, these services have to be delivered, which requires some kind of personnel and vehicle planning as well as real-time disposition (i_2). Finally, one needs to invoice the delivered services (i_3). A service-oriented approach may suggest decomposing some of these top-level services, resulting, for instance, in a sales/pricing and customer relationship management service. This is what we expect given a rational, top-down approach to EA planning.

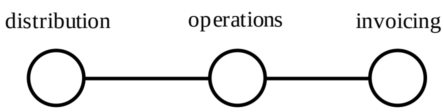

Fig. 2. A typical waste management process

However, our analysis of the company's grown IT landscape supports a different view towards bricolage and ad-hoc evolution. Drawing on data from the company's enterprise architecture repository, Fig. 3 shows a network plot representing the IS architecture in the waste operations domain. The data was collected in a real requirements engineering project by the company over a 3-month period in 2011 and it was complemented by 13 interviews with IT managers, developers, and business unit heads over a 6-month period in 2012. To construct the visualization, we coded the company's IS architecture into an n x n adjacency matrix $\boldsymbol{A}$. Within the figure, each node represents an IT application. The links represent integrations among systems. The color of the nodes denotes which organizational unit owns the system, e.g. bluish systems are owned by the corporate or headquarter IT department. In addition, numerous systems are maintained and operated by business units. The size of the nodes shows the number of integrations, which is denoted as ‘degree’ in network analysis terminology. Critical systems with numerous integrations are larger while applications with few integrations are smaller. The three systems that are most important for our theorizing are surrounded by light-bluish cluster boarders: SAP – used for invoicing and financials, Memo – an operations and logistics system operated mainly in the company’s southern regions, and Recyclix – another ERP and logistics system.

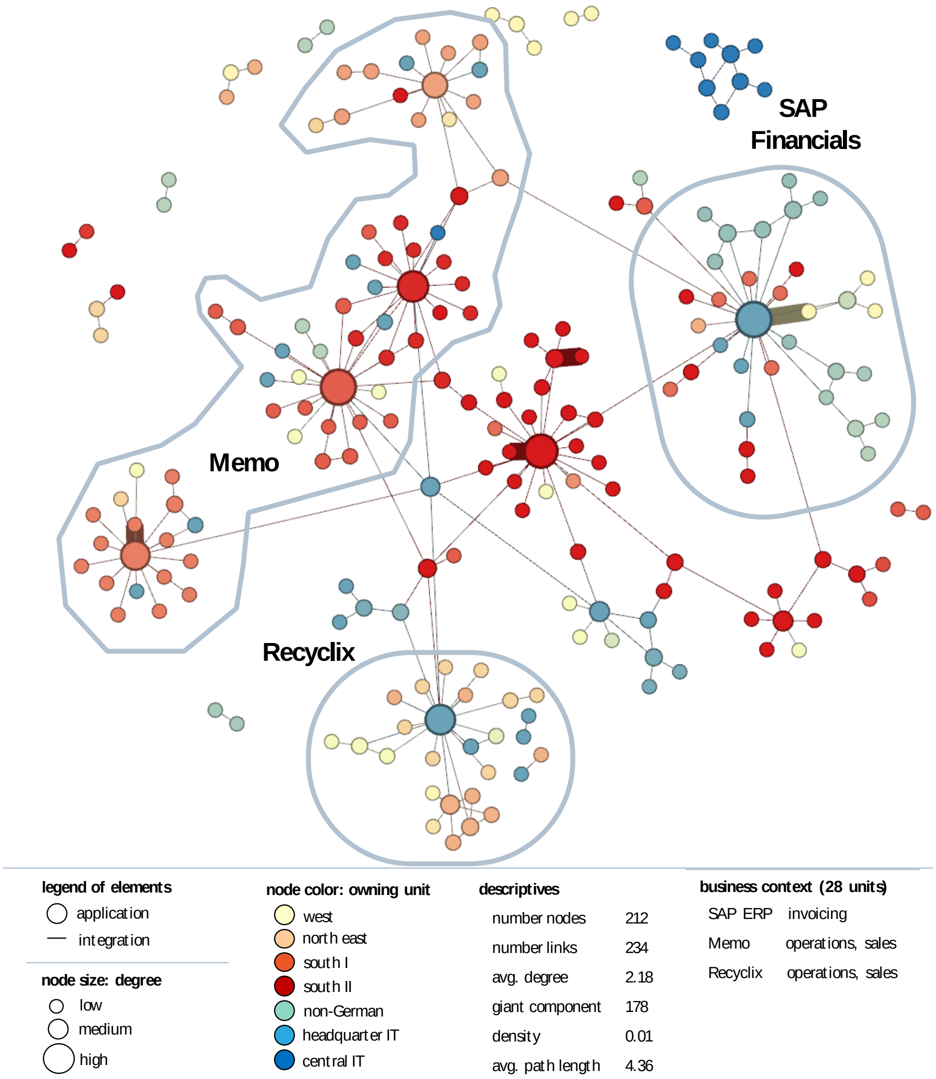

Fig. 3. Recycle Inc. as an example for a grown IT landscape

3.2 A Network Model of Growing IS Architectures

We next introduce a model of a growing network where new agents enter a network sequentially, one at a time, and select technologies (or platforms, standards). Think of an IT manager confronted with new business requirements to deliver a distribution solution, as in the waste management process. The manager will implement the application, which materializes as a node in our model that integrates with other nodes ($i_1,\ldots,i_n$) via links. For example, when selecting a distribution solution (i_1), the IT manager could consider integrations with operations (i_2) and invoicing (i_3).

We now introduce the agents' strategic decision-calculus to select technologies by turning to Brian Arthur's path dependence model [8]. As shown in Table 1, two types of equally-distributed agents, *r* and s agents, maximize their utility when selecting which technology platform *A* or *B* (e.g. SAP or mainframe) they should adopt. The selected technology becomes a property (attribute, feature) of a node.

Table 1. Agent decision calculus. Adapted from [8]

	Platform A	Platform B
R-agent	$\mathbf{a_{RA} + b_R N}$	$\mathbf{a_{RB} + b_R N}$
S-agent	$\mathbf{a_{SA} + b_S N}$	$\mathbf{a_{SB} + b_S N}$

The agents' decision function is based on two main ingredients: individual inclinations and network influences. In our context of IS architectures, the agents' base utilities denote solutions' ability to cover a specific process whereas network influences denote their utility from integrating with other departments, regions, and systems. In detail, *a* is the agent's preference towards one of two technologies *A* or *B* within the architecture. In addition, *bN* is the network influence where *b* is the network multiplier and *N* is the size of the network. Consistent with [8], we assume positive network multipliers, which corresponds to benefits for an agent to adopt the same technology as its peers (strategic complementarities), as this ensures compatibility and data exchange [32] or learning from the experiences of others [33]. Moreover, integrating new applications based on ill-fitting technologies would often impose additional costs from conversions or manual efforts. We assume that influences materialize in links between different nodes. For reasons of simplicity, we don't consider link directions.

A look at the agents' decision function reveals that, in this simple conceptual model, agents will be influenced by the entire network ("*N*"). Consistent with [34], we therefore unpack "*N*" taking into account interaction patterns between individual agents. To achieve this, we turn to models of network formation [15, 35]. These models explain to which existing nodes a new node will form links to, which equips them with a greater power than urn-type models to consider selective network influences.

Different classes of network formation models have been suggested. One may utilize a *random growth model* [15] in which new nodes entering the network form links to existing nodes uniformly at random. Furthermore, one may think of a *preferential attachment model* where new nodes entering a network connect to existing nodes with probabilities proportional to their degree [36]. We, however, find a third class of models superior for our analysis – *hybrid random growth models* [15]. These models set themselves apart from other random growth models by fitting real degree distributions, clustering coefficients, and other structural characteristics more closely [15].

Drawing on a hybrid random growth model by Jackson and Rogers [9], the main idea is illustrated in Fig. 4. Let m be the absolute number of links that a new node forms and let α be the real-valued degree of preferentiality ($0 < \alpha < 1$). Then, $\alpha * m_R$ links are formed uniformly at random by attaching to random nodes ("meeting strangers"), as shown in Fig. 4a, and $(1 - \alpha) * m_{NW}$ nodes are formed by traversing adjacent links ("meeting friends-of-friends"), as illustrated in Fig. 4b. We replace N in the agents' calculus in Table 1 by the extended growth logic $\alpha\, m_R + (1 - \alpha)\, m_{NW}$.

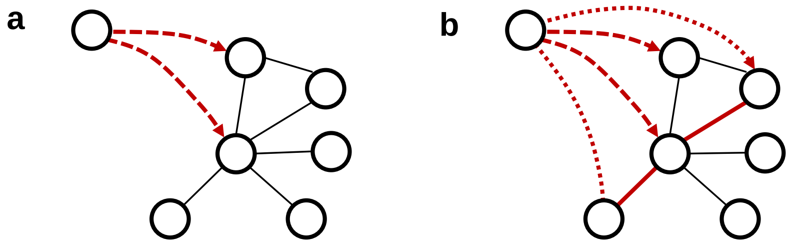

Fig. 4. Meeting strangers and friends-of-friends in hybrid random growth model by [9]

As illustrated in Fig. 5, two main parameters thus describe our network's growth logic: its degree of integration (m) and its degree of preferentiality (α). The *degree of integration* is a measure of a network's connectedness where increasing levels of connectedness will correspond to a more densely connected network. In these networks, individual nodes will have more ties among each other and average paths lengths will become smaller. Referring to IS architectures, such situation describes a more centralized architecture with higher levels of integration as illustrated by core banking or airline inventory systems. The *degree of preferentiality* measures the extent to which new nodes will attach predominantly to hubs; or put differently, to what extent are resources pooled to already important core applications [7]. One may think of a hub-and-spoke network as one extreme whereas a completely regular network would be the other extreme. However, growing networks will tend naturally towards clustering as nodes gain links as a function of their age and not only their degree [9].

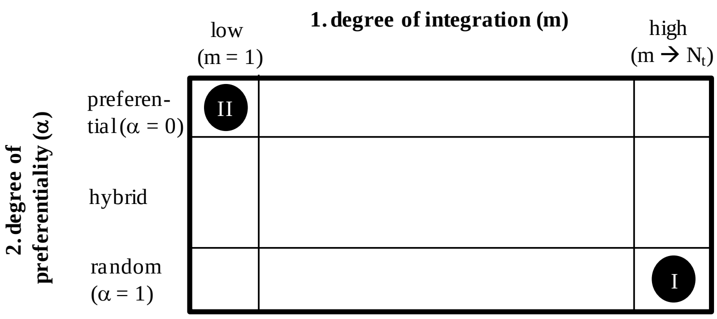

Fig. 5. Main parameters and extreme points in hybrid random growth model

Within the framework of Fig. 5, we can discuss two extreme points that are particularly important for our theorizing. Firstly, we can refer to a situation where the network grows with degrees of integration (m) exceeding the number of nodes in any period (Fig. 5-I). This designates a situation in which any new system needs to be integrated with any existing one. Then, we expect that – with growing networks – network influences increase linearly with the network size; at some point the agent's base preferences become subordinate and any new IT solution uses the predominant solution. This is the classic case of lock-in to one technology as described by [8]. As another extreme, imagine a situation in which any new node forms exactly one link to the architecture and attachment is preferential (cf. Fig. 5-II), i.e. each new IT system integrates with one important "hub" exclusively. Then, we expect that the network clusters around several hubs which may be – depending on the initial configuration – based on different platforms (technologies, standards). Hence, the network grows homogeneous around individual hubs but diverse clusters evolve.

4 Insights from Agent-based Simulations

4.1 Experimental Setup and Dependent Variable

We implemented the model in Netlogo 5.0.3, an agent-based simulation tool, as it allows for graphical interaction and because of its useful extensions, i.e. for networks.

We turn to one experiment that illustrates insights we can derive from the model. Fixing the preferentiality to hybrid ($\alpha = 0.5$), we vary the degree of integration (m) in a setting with $k = 2$ technologies. We chose to vary the degree of integration as [7] showed its importance in modeling different kinds of emerging IS architectures. Empirical data informed our decision on model runtimes to guarantee firstly the model converging to equilibrium while secondly staying in proportion to empirically observed sizes of IS architectures.

As a measure of technological lock-in in an architectural network, we turn to the **diversity index** [37]. The diversity index is also known as Herfindahl index in economics where it is useful to measure, for instance, the concentration of vendors in a market. Is the market concentrated to one vendor exclusively or is the market shared equally among several vendors? The diversity index also serves useful because it has been transferred recently from market contexts to EA's where it can be used to quantify the heterogeneity of technologies in an IT landscape [38]. More specifically, we express the diversity index D, our dependent variable, as follows:

$$D = \frac{1}{\sum_1^k p^2} \quad (1)$$

The mechanics are straightforward: let p be a non-negative selection probability that is based on the distribution of k technologies in the network. Then, the diversity index is the squared sum of the selection probabilities for all technologies. As an example, we refer to a network in which agents can select between two technologies and both technologies are distributed equally in the network, i.e. both have a 50% share. Then, p is ½ for each of the technologies and $½^2 = ¼$ and, thus, ¼ + ¼ = ½. We use the inverse diversity index, hence, 1 / (½) = 2. Its maximum always equals the number of technologies; it is 2 in our example. Its minimum is 1 if all nodes adopt one technology and the network is concentrated exclusively to one technology. Thus, the diversity index helps to identify "lock-in" situations in history-dependent processes as inertia materializes in decreasing diversity over time where the system eventually converges to a state in which one technology comes to dominate exclusively [39].

4.2 Results

Fig. 6 turns our attention to results from different sample runs. In Fig. 6a, we see a run for high degrees of integration (*m* = 20). As expected theoretically, for high levels of integration, the network rapidly locks in to one technology and all subsequent agents select the dominant platform as can be seen by the agglomeration dynamics in Fig. 6a.

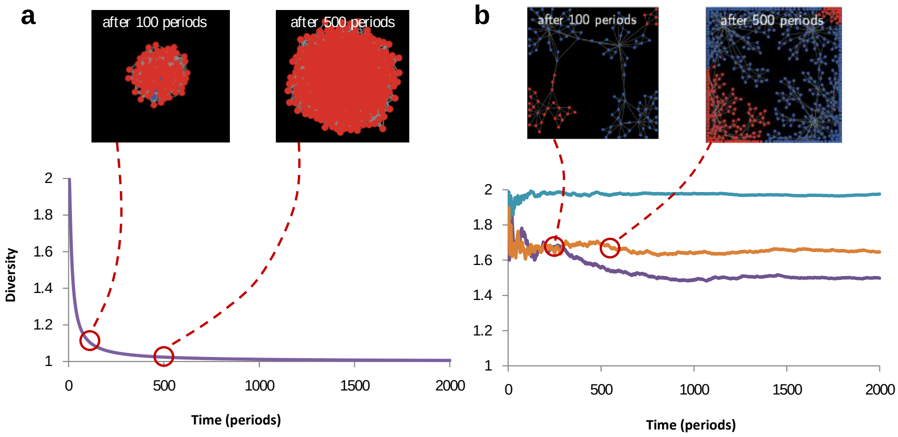

Fig. 6. Comparing diversity for (a) high and (b) low degrees of integration

Pointing to our first main observation, the three lines on the right (Fig. 6b) show sample runs for low degrees of integration (*m* = 1). From the plot we see that while it is possible that the network locks in to one technology, it is unlikely. What is more likely is that a hybrid state with "islands of shared technologies" will arise. The network convergences to one ratio of technologies (e.g. 80:20, 60:40). This configuration becomes constantly reinforced as can be seen from the flattening of the diversity curve in Fig. 6b. Transformation barriers build up by new elements being attached constantly to either of the predominant hubs. In Fig. 6b, the two hubs on the bottom left and top right feature technology *A* (red) while the other hubs start with technology *B* (blue). This early imprint becomes reinforced by constant growth around the hubs.

This result is particularly important because as it highlights that the emergence of technological silos can be expected as a consequence of an IS architecture growth process with low degrees of integration. It also shows the importance of timing as late interventions make it more likely that a 'rigidity trap' has occurred in which the initial configuration has been stabilized (i.e. after 200-500 periods in our simulation).

Table 2 shows numerical results for varying degrees of integration (*m*). We see clearly, that diversity decreases with increasing degrees of integration. For low degrees of integration (*m* = 1), "islands of shared technologies" arise that grow increasingly homogenous. For medium degrees of integration (*m* = 3), diversity decreases and clustering dynamics are less pronounced. The more integrated the network becomes (*m* = 7), the more susceptible it becomes to technological lock-ins. As a by-product, c*hange complexity* will also increase as nodes will gain comparatively more links resulting in a higher average degree of the network. Thus, another main observation is that the lock-in effect for high degrees of integration goes together with increasing change complexity in a highly-standardized but rigid architecture.

Table 2. Effects of varying degrees of integration (m) on diversity (D) fixing all other parameters. Batch simulation results were averaged over 1,000 simulation runs.

Degree of integration (m)					
Low (m = 1)		Medium (m = 3)		High (m = 7)	
Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
1.53	**0.35**	**1.26**	**0.34**	**1.01**	**0.03**

4.3 Discussion: Implications for the Recycle Inc. Case

We can now turn to a discussion of the results' similarity with data from the Recycle Inc. case. As shown in Fig. 3, the firm's IT landscape was characterized by comparatively low levels of integration. Within a network of 212 applications, we found 234 integrations, resulting in an average degree of 2.18 (as each undirected link may be written as one incoming and outgoing link). Hence, the network is rather sparse with pronounced clustering around important "hubs" such as Memo, SAP, or Recyclix. We denote these hubs as core applications or application platforms.

How did the growth logic of the architectural network affect path building processes? Firstly, we turn to the architecture's structure and its consequences for change complexity. The network's clustered form and its "long-tailed" degree distribution suggest a preferential growth process. These properties points to "Matthew effect" where several important hubs' embeddedness in the network became increasingly reinforced over time ("the rich get richer" and the "poor get poorer"). Interviews also showed that IT investments had been preferential, pooled to different core applications (and not functional domains). Preferential growth, however, made a consolidation of the IT landscape increasingly difficult as different core applications had grown as separate ecosystems of complementing systems (e.g. controlling cockpits or Excel-based reporting tools). This let us conclude that even in IS architectures with low degrees of integration, change complexity becomes problematic *when* medium or high degrees of preferentiality (pooling of resources to different hubs; as in simulation setup) result in a Matthew effect fostering the emergence of segregated silos.

Secondly, we consider the architecture's exposure to technological lock-ins. Taking into account the network's sparseness, our simulations let us suspect that different clusters lock into different technologies. Indeed, our interviews supported this view and some hubs overlapped widely in functionality (e.g. Recyclix and Memo). However, our empirical data did not confirm that the spokes were primarily based on the same technology as these hubs (refer to Fig. 6b). In contrast, we found a surprising technological variety in Recycle Inc.'s architecture (e.g. refer to the colors in Fig. 3). While some spokes where indeed based on the hub's platform, many were Excel-based or proprietary. Alongside [40], our data thus suggest the importance of additional factors (e.g. ease-of-use, availability) in explaining the observed heterogeneity.

Altogether, our analysis shows that trends towards (a) clustering and (b) technology agglomeration around hubs both contributed to constantly reinforce a path towards "fragmentation". The firm's CIO tapped into the underlying factors: "acquisitions, little standardization on the vendor side, thus one turned to proprietary solutions and then we have also been very withholding with […] the positioning of the IT, in the sense of new topics, which has, over the last couple of years, involved a restrained investment policy, which, as a side-product, as demands have still been existent but remained at the business units, produced a situation where in the surroundings a lot of uncontrolled growth took place." This results today in a 'rigidity trap' that business units aimed to counteract by constantly adding new IT systems responding to emerging demands, which further piled up barriers moving to a unified business solution.

5 Concluding Remarks

This paper aimed at gaining a better understanding of how an IS architecture network's growth logic affects change complexity and technological lock-ins. Drawing on a network perspective, we suggested a model of path building that considers a set of flexible growth logics where new IT systems, necessary to support emerging business requirements, link to the existing architecture based on a mix of random and preferential attachment. The model highlights how segmented structures around important hubs can emerge and how technologies can cluster in "silos" or "islands of shared technologies". These experimental findings served useful to explain tendencies towards fragmentation in a recycling company's grown IT landscape.

Before sketching theoretical implications, we emphasize conditions that limit the generality of our approach. Firstly, we have chosen an unweighted network. However, integrations come in different qualities. We thus performed an additional analysis recoding integrations in two categories: automatic (i.e. online, semi-automatic, or batch) and manual ones. Table 3 shows results. We found that, of the 234 interfaces, roughly 50% had been automated while equally significant amounts involved manual steps. This raises questions on how integration qualities link to an IS architecture's inertia potential. In particular, one may suspect that automatic integrations are more exposed to inertia as they require long-lasting contracts, e.g. on a syntactic and semantic level.

Table 3. Manual and automatic interfaces in Recycle Inc.'s IS architecture

	Automatic	Manual	Missing
Value	118 (50.4%)	107 (45.7%)	9 (3.8%)

Secondly, we focused on one-time decisions of agents that aim to support business requirements by augmenting new IT solutions with integrations to the existing architecture. Out of scope have been other events that transform IS architectures such as shrinking, death, splits, and mergers (refer to [7] and also more generally to [41] for social networks). Thirdly, we assumed irreversibility of agent's decisions. In reality, organizations have limited switching points to change their IT platforms given resource restrictions and so forth. However, future research could investigate network interventions that tap into the extent to which trotted paths that have been built up over extended time intervals can be left. Fourthly, we assumed rational agents that select technologies based on individual inclinations and network influences. Our agent's decision calculus is a flexible module that can be extended in future research to account for adaptive expectations, learning effects and bounded rationality. This presents interesting future research challenges.

In addition to replicating our approach in other organizational settings, especially in those in which less dispersed structures are expected, future research aims to develop a more general model of IS architecture evolution. Informed by longitudinal data, such model would be useful to examine whether an IS architecture is in a phase of expansion or consolidation and to support decisions on transformation scenarios.

Turning in conclusion to theoretical implications, we offered a novel, path dependence perspective on enterprise transformations that goes beyond assuming that evolution equals planning. In contrast to [24], we don't believe that the notion of "chaos" is appropriate to describe the evolution of enterprise architectures and we instead suggest a perspective of path dependence as a useful reference point for further theory building on the emergent dynamics of organizational IS architectures. While both – chaos and path dependence theory – share some notions such as fix point attractors, path dependence theory puts much more emphasis on nonlinear positive feedback dynamics, which can be observed, modeled, and potentially controlled in real world settings. We believe that understanding organizational IS architectures as "complex networks" [42] and managing them by network models, as the one presented in this article, is a long overdue extension to our toolkit as enterprise architects. Our contributions are as follows. Firstly, we introduced a network model that formalizes path building processes in organizational IS architectures by a set of flexible growth logics. We believe that future work can fit parameters such as new systems' degree of integration and preferentiality directly to real world problem instances, which will shed new light on the growth logics of architectural networks and which will help to uncover their "hidden structure" [30]. In relation to that point, our model helps to reason about (*i*) how structural complexity emerges in increasingly interdependent IS architectures and (*ii*) how technological variety develops as a function of the current distribution of technologies in the architecture. Secondly, our results point to potential pitfalls that can occur when IS architectures grow increasingly complex and enterprise transformation initiatives miss a critical point of no return. Then, critical systems that are deeply embedded within the organization often stay operational despite capability shortcomings or missing vendor support [4]. Our results point to the interesting theoretical possibility to sense such 'rigidity traps' earlier. Finally, as a by-product, we developed a simulator that can be foundational for a management-dashboard.

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