Matthew Effects, Criticality Traps, and Redundancy Slips in Digital Infrastructures: Evidence from Two Cases

Karl Akbari
Hochschule Bremen
karl.akbari@hs-bremen.de

Abayomi Baiyere
Queen's University
a.baiyere@queensu.ca

Till J. Winkler
University of Hagen
till.winkler@fernuni-hagen.de

Daniel Fürstenau
Free University of Berlin
daniel.fuerstenau@fu-berlin.de

Abstract

The goal of this study is to explore evidence for a Matthew effect in system embeddedness. The secondary objective is to understand the relationship between the Matthew effect and (1) a "criticality trap," a situation where excess inertia leaves an organization trapped in a system or (2) a "redundancy slip," where low embeddedness leads to system discontinuance. Through two case studies, we provide robust evidence for all three effects. In a media firm, we use nine years of panel data to demonstrate cubic growth in system embeddedness. In a manufacturing firm, we validate that the Matthew effect can lead to a criticality trap, but we also show that some systems experience a redundancy slip. Our practical insights are crucial for identifying and managing embedded systems in digital infrastructures. The Matthew effect is a powerful mechanism driving the evolution of systems and, consequently, digital infrastructures.

Keywords: Matthew effect, system embeddedness, criticality trap, redundancy slip

1. Introduction

The received knowledge from prior literature is that systems more embedded in an infrastructure are more inert because they are deeply entrenched in routines and processes and have integrations with many other systems (Furneaux & Wade, 2011; Fürstenau et al., 2019). Embedding (and de-embedding) a system in a digital infrastructure is thereby understood as a process (Ciborra, 2000; Hanseth & Rodon Modol, 2021). This process is not necessarily expected to be one of *linear* growth but will show distinct patterns based on a system's existing level of embeddedness and may turn out differently as systems age (Fürstenau et al., 2019; Tiwana & Safadi, 2024).

However, while the notion of a *Matthew effect* has been posited (Fürstenau et al., 2019), stating colloquially that systems that are rich get richer, while systems that are poor get poorer, we know little about its empirical manifestations. This is unfortunate because while we know that embeddedness influences governance-architecture fit which in turn influences longevity (Akbari et al., 2024), today we have limited empirical evidence on the change patterns of system embeddedness. Our primary objective is to *explore whether there is evidence for a Matthew effect in system embeddedness*.

Experience and anecdotal evidence show that often the point of no return—when system cease to provide meaningful value to users—will be missed. The resulting incapacity to abandon, replace, or discontinue systems in the face of logical reasons can lead to what we call a *"criticality trap."* Conversely, when a system fails to be sufficiently embedded or loses its embeddedness, it risks being perceived as irrelevant, leading to a phenomenon we call *"redundancy slip."* Thus, our secondary objective is to better understand how embeddedness is related to criticality trap and redundancy slip.

We conduct two in-depth case studies: one primarily qualitative and one primarily quantitative. Both cases share an interconnected network view of system embeddedness as a common denominator. The first case (MEDIA) establishes the *Matthew effect* using 9 years of panel data. It models the growth in system embeddedness as a function of system embeddedness in the previous period and tests the functional form (linear or polynomial). Additionally, it examines the relationship between embeddedness, changes in embeddedness, and the likelihood of discontinuance. The second case (MANUFACTURING) explores the link between system embeddedness and the criticality trap/redundancy slip via qualitative data.

Our quantitative study finds robust evidence for the *Matthew effect* and suggests that a polynomial model fits best to the data. This shows that system embeddedness grows superlinear, in our model with a cubic polynomial. Furthermore, we find evidence for criticality trap and redundancy slip. Our qualitative study finds that criticality trap is often diagnosed when it is too late. Too much embeddedness can lead to

URI: https://hdl.handle.net/10125/109563
978-0-9981331-8-8

criticality trap, where an organization can feel stuck with a system that is simultaneously crucial in some areas and useless in others, too little embeddedness gives way to redundancy slip, leading to a higher likelihood of discontinuance of these systems.

Our contributions are twofold. First, there was previously only anecdotal evidence and sparse empirical accounts of a Matthew effect in system embeddedness. We advance practical knowledge that can support business and IT managers, system, and enterprise architects in firstly identifying embedded systems in a company's digital infrastructure and secondly understanding their corresponding inertia, criticality, and negligence implications.

2. Theoretical Background

It is established that important dimensions of system embeddedness that undermine the formation of information systems (IS) replacement intentions are technical integration and social factors (Furneaux & Wade, 2011; Fürstenau et al., 2019; Rinta-Kahila et al., 2023). Consistent with prior authors, we refer to system embeddedness as the degree to which a system depends on linkages among component elements or other systems to deliver its intended functionalities within an organizational context.

Furneaux & Wade's (2011) empirical study found a negative relationship between system embeddedness and replacement intentions. While their study systematically explores this relationship, it presents a limited, aggregated view (Williams & Pollock, 2012) by relying on a survey design that allowed respondents to choose only a single system, thus overlooking the complexities and differential evolution of various components in a digital infrastructure.

Consequently, we adopt an interconnection view on digital infrastructures when evaluating system embeddedness. This perspective has a long tradition in digital infrastructure literature (Henfridsson & Bygstad, 2013; Pipek & Wulf, 2009; Star & Ruhleder, 1996; Vaast & Walsham, 2009) and in broader works on technical, social, and economic networks. According to Granovetter's (1985) seminal work on social structures, an actor's embeddedness depends on the amount and intensity of linkages with others. Network analysis thus plays a central role in understanding embeddedness and its manifestation in social and economic structures (Wasserman & Faust, 1994). An interconnection view also aligns with technical studies on the properties of engineering systems (Baldwin et al., 2014), which have led to research on system-level dependencies (Dreyfus & Iyer, 2008; Lagerström et al., 2014; MacCormack et al., 2016).

Drawing on the notion of self-reinforcing processes, we suggest that preferential growth results in some systems experiencing strong growth while others shrink drastically. Since the existing embedding plays a role, heavily embedded systems become even more embedded, while less embedded systems become lighter. This growth pattern resembles the *Matthew effect* discussed in other disciplines, where it has been used to demonstrate the concept of a valuable resource continuing to increase in value, while a less valuable resource conversely diminishes in value (Merton, 1968; Yegorov et al., 2022).

Corresponding to the notion of valuable and less valuable resources, this study distinguishes between heavy and light systems qualitatively and quantitatively. The qualitative distinction emphasizes the relative importance of systems, and the value placed on them within the infrastructure by the organization. In contrast, the quantitative distinction relates to the number of connections attached to the system. From an organizational perspective within a specific digital infrastructure, a heavy system is one of high or growing importance or has a relatively high number of connected systems. Conversely, a light system is one of low or waning importance or has a relatively low number of connected systems (Fürstenau et al., 2019).

In the light of these considerations, we aim to observe the Matthew effect and ask:

RQ 1: What is the functional form of the Matthew effect (linear or polynomial)?

Observing the Matthew Effect provides valuable insights into the dynamics of system embeddedness, but it is not without consequences. The reinforcing effect for heavy systems and the subtracting effect for lighter systems both have implications for system persistence or discontinuation within the organization. We focus on two key factors: the criticality trap, which plays a pivotal role in the embeddedness of heavy systems, and the redundancy slip, which becomes particularly relevant for lighter systems.

The notion of criticality trap reflects the discrepancy between an organization's need to discontinue and its actual impetus to discontinue systems in a digital infrastructure due to their accrued importance and inertia. Criticality trap provides a theoretical explanation for how system embeddedness can impede the discontinuance of a system. This situation becomes salient when an embedded system's criticality—typically in the form of its position of importance and perceived value—becomes reinforced

over time due to its increased embeddedness (Fürstenau et al., 2019). Another implication and concern with criticality trap are that the very systems that have proven valuable and perhaps key to an organization's success may become detrimental to their progress if not carefully managed. This is a situation where a capability becomes a disability. Herein lies the "trap". Such situations where capabilities become disabilities have been characterized in prior literature as difficult and challenging dilemmas for organizations to navigate (Baiyere & Hukal, 2020; Christensen & Overdorf, 2000). Criticality traps thus introduce uncertainty to a rather stable setup (Wimelius et al., 2021) and calls for attention from future scholars and practitioners of digital infrastructures.

Conversely, when a system's embeddedness remains low or wanes, we propose a risk for a redundancy slip which can be defined as the discrepancy between the need to retain a system and the impetus to discontinue it, driven by the system's small or diminished role and embeddedness, resulting in the loss of investments in innovations that never gained sufficient traction within the organization. As the system loses embeddedness, it naturally becomes an easy candidate for replacement whenever the need to make such a change arises (Fürstenau et al., 2019; Rinta-Kahila et al., 2023). One implication of the redundancy slip is its potential to result in situations where more beneficial systems are sacrificed and given up in preference for more embedded systems, even though they may have capability shortcomings. For example, during the covid pandemic, many organizations adopted a flurry of virtual collaboration tools such as Microsoft Teams, Zoom, Slack, and Adobe Connect, among others. The emerging reality in some organizations is that less embedded systems were easy candidates to be dropped quickly even though the alternative solutions may serve their purpose better (Matyszczyk, 2021). This is a pertinent consideration, particularly in cases where organizations invest heavily in some systems but such systems flounder because they never get fully embedded in the digital infrastructure. In other words, the propensity for a system to get embedded in a digital infrastructure could be a useful determinant of the potential success and utility of the system.

RQ 2: How is system embeddedness related to the criticality trap and the redundancy slip?

3. Methods

3.1. Data Collection & Analysis Strategy

To assess the Matthew effect as well as the criticality trap and redundancy slip, we performed a stepwise data analysis process. This was repeated at every timepoint.

List Information Systems. The first step was to collect the specific information system unit to be assessed, which involves defining the system clearly and breaking it down into subunits for analysis (Hanseth & Rodon Modol, 2021). This study focuses on *applications.* Applications are software-based collections of IT functionalities supporting user work practices (Hanseth & Lyytinen, 2010).

Identify Linkages and Create Network. The next step is to identify the relationships between individual applications, with a focus on the interfaces connecting them. The study considers direct "depends on" or "uses" relationships as the most important form of interface (Pipek & Wulf, 2009; Vaast & Walsham, 2009). Next, we created a network of the systems. The structure represents the systems as nodes and the links as information flows, revealing underlying dependencies among systems and providing a clearer picture of the connections within an organization (Dreyfus & Iyer, 2008; Lagerström et al., 2014).

Assess System Embeddedness via Network Analysis. This step focuses on analyzing the degree of embeddedness of each system in the infrastructure (see Figure 1 for an example). The study uses degree centrality to assess a node's influence, measuring the number of direct neighbors (Dreyfus & Iyer, 2008; Wasserman & Faust, 1994).

The study classifies systems as *heavy (high degree centrality) or light (low degree centrality)*, laying the ground for analyzing change patterns as explained next.

Analyze Change Patterns. By looking at changes of system embeddedness over time, we observe which change patterns occur and how previous system embeddedness influences future embeddedness, and whether we observe a Matthew effect. We seek to assess the shape of the growth patterns to determine whether the growth is linear or follows a nonlinear pattern. Specifically, we will examine quadratic and cubic effects to better understand how the Matthew effect manifests in the data. If there is a positive linear effect of embeddedness on the growth of embeddedness, it suggests that higher embeddedness leads to stronger growth, indicating that rich systems get richer. This effect would accumulate over time given our temporal data. A quadratic effect would indicate an accelerated growth, meaning that rich systems become richer at an even faster rate, pointing towards an accelerated Matthew effect. Finally, if we observe a cubic term, it will imply a more complex pattern: poor systems get poorer, intermediate systems

grow at a constant rate, and very heavy systems grow disproportionately strong (Ostertagová, 2012).

Perform (Dis-)Continuance Analysis. Criticality trap and redundancy slip are analyzed. For this analysis we further consider how embeddedness manifests for highly and lightly embedded systems and their consequence for the digital infrastructure. In Study 1, we observe how embeddedness and growth of embeddedness influence discontinuance decisions. In Study 2, we also seek to comprehend the reasons behind the persistence of heavy systems and transience of light systems and identify catalysts for change.

3.2. Empirical Cases

We conducted two in-depth case studies to attend to our research objectives (Yin, 2017).

The first case company—MEDIA—is a European television broadcaster which has around 4,500 employees and was established in the 1960s. We started our observation in 2015 and observed the company's application architecture at five timepoints (2015, 2016, 2018, 2020, 2024).

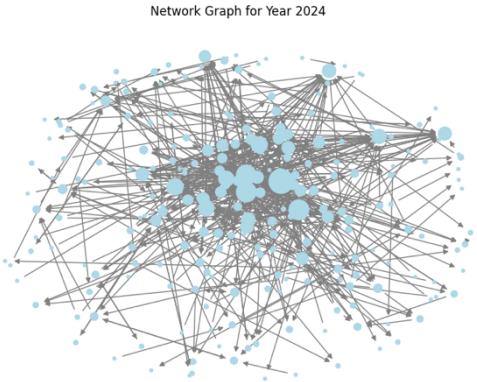

Figure 1: MEDIA's network structure in 2024. Nodes represent applications, with their size proportional to their embeddedness, edges represent interfaces between the applications

Data for this study were collected from the enterprise architecture repository of the organization, focusing on the business applications to observe changes over time. We retained applications that were present in at least two distinct periods to analyze growth patterns. Embeddedness, as previously described, was evaluated for each application, and the change in embeddedness was calculated as the difference between the embeddedness at time *t* and the embeddedness at time *t-1*. (Dis-)continuance was measured by whether the application was retained between observational periods. Additionally, we controlled for the age of the application.

The second case company—MANUFACTURING—is a Finnish company operating in the manufacturing industry, which belongs to a larger conglomerate of companies. We focus on this specific subsidiary company, which has about 500 employees and specializes in hi-tech manufacturing machines and robotics. The company has existed in different forms for about 120 years. We entered the field in MANUFACTURING in 2015, and the study continued until 2019. Given that the company has been able to transform its identity over several decades, it is indicative of a potential for the company to be a useful case context characterized by legacy systems as well as the impetus to adopt innovative systems for the rapidly evolving robotics industry.

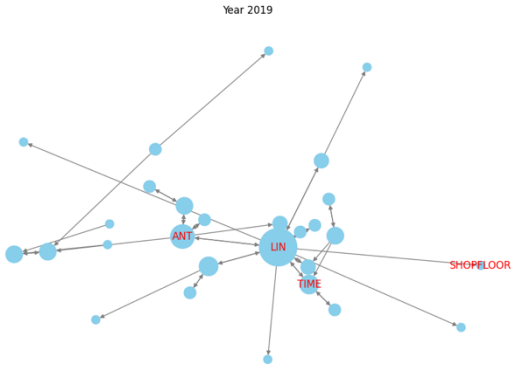

Figure 2: MANUFACTURING's network structure in 2019. Nodes represent applications, with their size proportional to their embeddedness, edges represent interfaces between the applications

For this case, we obtained data from the enterprise architecture repository of MANUFACTURING (cf. Figure 2). As the observation period was too short, it was not possible to run a quantitative study focused on change patterns as in the case of MEDIA. Therefore, we adopted a qualitative approach to answer RQ2. After identifying heavy and light applications, we conducted semi-structured interviews to get a qualitative assessment not only of whether or not these applications' size is a result of a Matthew effect but also to assess the consequences of such an effect, i.e., the source of inertia within the infrastructure and to help us uncover the underlying rationale and mechanisms for such inertia tendencies. We conducted 19 interviews in total from 2016 to 2017. The participants of the interviews were a combination of IT managers, team members, and business managers in charge of different non-IT processes within the company. The business managers are typically those who use and are familiar with the key systems identified as critical in the study. The interviews lasted

60-90 minutes and were recorded and transcribed for thematic analysis (Mayring, 2019).

We observed participants' daily routines and engaged in discussions to understand their system choices and usage. This data, along with insights from two IT management meetings and a workshop on digital platform development, supported our qualitative triangulation of system embeddedness and its impact on digital infrastructure.

4. Results

4.1. MEDIA Case (Study 1)

A one-way (individual) fixed effects model was used to analyze the impact of initial degree and the difference in days as a control variable on embeddedness growth, i.e., the change in the number of connections for each app compared to the last observation (Wooldridge, 2010). The panel data comprised an unbalanced panel with 217 applications observed over 1 to 4 time periods, yielding a total of 724 observations. The mean degree was 2.8, the median degree was 2 (for an evolution of the network cf. Figure A1 in the Appendix).

To determine the most appropriate model for our data, we tested three polynomial models (linear, quadratic, and cubic) to assess growth and to examine whether a Matthew effect is present and, if so, to identify its shape. A Likelihood Ratio Test (LRT) is performed to assess the goodness of fit of a statistical model by comparing the likelihoods of nested models, specifically in this context, to determine whether the inclusion of additional parameters in polynomial regression models (linear, quadratic, and cubic) significantly improves the model's fit to the data (Wilks, 1938). The LRT indicated that the cubic model provided a significantly better fit compared to the linear and quadratic models (Table 1).

Table 1: Likelihood ratio tests for model comparison

Comparison	LogLik (1)	LogLik (2)	df	Chi-square
Linear (1) vs Quadratic (2)	−1,085	−1,079	1	10.82 ***
Linear (1) vs Cubic (2)	−1,085	−1,042	2	84.85 ***
Quadratic (1) vs Cubic (2)	−1,079	−1,042	1	74.03 ***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Additional metrics such as the AIC and BIC values and the highest R-squared, support the finding that the cubic model has the best fit among the tested models (see Appendix, Table A1). This supports the inclusion of higher-order terms to capture the complexity of the relationship between degree and growth.

Table 2: Regression results for MEDIA

	B (Std. Error)
Constant	-2.355 (0.374) ***
Degree	1.002 (0.082) ***
Degree^2	-0.036(0.005) ***
Degree^3	0.0004(0.0001) ***
Age (Days)	-0.0001(0.0001) **
Panel fixed effects	YES
R-Squared	0.297
F-statistic	53.208 ($p< 0.001$)
n	217
T	1-4
N	724

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

To conserve space, we focus on interpreting the cubic model. Estimates for linear and quadratic models are in the Appendix. For the cubic model (cf. Table 2), the *F*-statistic was significant ($F(4, 503) = 53.208$, $p < 0.001$), indicating that the overall model was a good fit with an R-squared of 0.297. The analysis revealed significant effects of degree (positive), degree squared (negative), degree cubed (positive) on the change in degree. Overall, this indicates that the higher the degree, the stronger the growth. Furthermore, the growth is s-shaped: For low degree systems the growth is lowest and even negative, for high degree systems, the growth is particularly strong. Figure 3 displays this relationship.

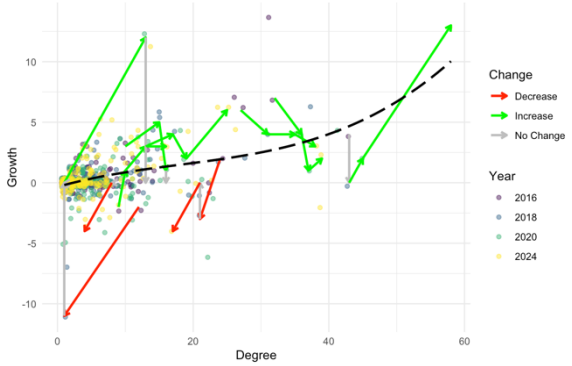

Figure 3: Relationship between system degree and growth over time, shown with panel data (2016, 2018, 2020, 2024, with 2015 as a baseline). Selected systems' growth trends are highlighted with green (increase) and red (decrease) arrows. The black

dashed line represents the polynomial regression trend.

The scatterplot presents observations from different years in different colors, to clarify this, we added the growth pattern of selected applications with arrows. The control variable was significant, indicating that older systems become less connected over time. The findings are consistent with the Matthew effect, as higher-degree nodes exhibit more substantial growth, emphasizing the importance of initial advantages in network dynamics.

Furthermore, the negative values of the curve for low degree values indicates that low degree applications more often shrink.

(Dis-)Continuance Analysis. Figure 4 shows that light applications (1-10 interfaces) have a higher likelihood of being decommissioned compared to heavy applications. Furthermore, embeddedness growth plays an important role. As applications lose embeddedness, the proportion of decommissioning increases, which aligns with the redundancy slip. Yet, even light systems that were growing have been decommissioned. For heavy applications (10+ interfaces), while there was some decommissioning among those that lost embeddedness, heavy applications that grew or maintained stable embeddedness were not decommissioned at all during our observational period—a finding consistent with the criticality trap.

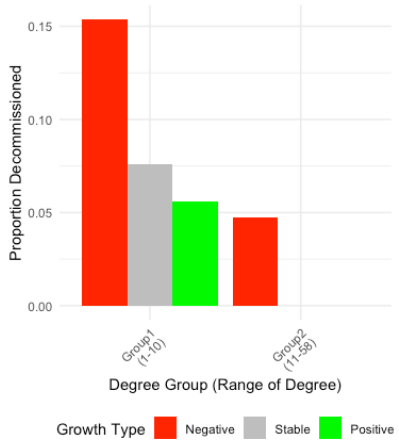

Figure 4: *Proportion of Decommissioning by Embeddedness Group and Growth Category*

To test the significance of the relationships observed in the descriptive statistics, a logistic regression analysis was conducted with decommissioning as the dependent variable, controlling for the year (cf. Appendix Table A2 for full results). The results indicated that heavy systems (compared to light systems) were significantly less likely to be decommissioned ($\beta = -2.39, SE = 1.04, p = .022$). Additionally, systems with stable or positive growth (relative to those with negative growth) were also less likely to be decommissioned, ($\beta = -0.95, SE = 0.39, p = .016$) and ($\beta = -1.15, SE = 0.55, p = .037$), respectively. These findings are consistent with theoretical expectations of redundancy slip and criticality trap in system decommissioning.

4.2 MANUFACTURING Case (Study 2)

While we were unable to reproduce the full analysis of the change patterns from the MEDIA case in MANUFACTURING due to data constraints, we were able to assess the system embeddedness and perform a (dis-)continuance analysis.

Figure 2 presents an overview of the applications and their integration within the digital infrastructure of MANUFACTURING (for a comparison over time please see Figure A2 in the Appendix). Until 2013, MANUFACTURING operated with IT as primarily a support unit. The IT unit traditionally consisted of an IT manager who led a group of IT professionals. The IT team has been keen on taking on new innovations such as cloud applications while also grappling with an installed base laden with legacy applications. With the growing demands on the company and the potential for digital disruption in the manufacturing business, IT became an increasingly important component of the organizational strategy. This led to an assessment of the status of the digital infrastructure.

The average degree of the 40 applications of MANUFACTURING is 2.25. The median of the degree is 1, indicating a skewed distribution in which some applications accumulate a high number of links while most applications are less connected.

To investigate the criticality trap and redundancy slip, we focus our qualitative analysis on two heavy applications, LIN, and ANT, and two light applications, TIME, and SHOPFLOOR IT. We selected two heavy applications that consistently added connections in and before our observational period, showing a clear trend of growth with no indication of stopping up to the point of our observations.

LIN and ANT as Examples for a Criticality Trap. LIN and ANT are the most embedded applications in MANUFACTURING, which is evidenced by their high centrality measures. Regarding LIN, according to one of the IT managers *"Of course the most integrated systems that we have are probably LIN … the older systems like LIN are hard and stiff and the integrations are always [such that] you have to build one [separately] for the system that you want to integrate. And those are costly."*

The data highlights the critical embeddedness of LIN in the infrastructure and how heavily dependent the company is on it, while also highlighting the difficulty of attempting to change the system. The CIO exclaimed "*There is no way in hell we can change LIN anytime soon! ...Everything is technically connected to LIN.*"

Regarding ANT, it is interesting to note that people stated that it should not grow, but it was still growing. One interviewee explained *"[ANT] was the old ERP system and is still used [in] the accounting financial department side"*. Interviewees noted that ANT was operating past its peak lifetime. Essentially, it was a system that should have been replaced for some time, but its importance and integration were hindering it. As noted by one interviewee: *"ANT is basically the side server ... [LIN is] a separate server but they're using things that talk to each other. So, they are getting to be a bit more integrated [into LIN]".* This was also indicated by our system embeddedness data which showed that it had gained in embeddedness despite these intentions to replace it.

TIME and SHOPFLOOR as Examples of a Redundancy Slip. These two applications are among many lightly embedded applications in MANUFACTURING's infrastructure. TIME was used for a specific organizational function—timekeeping. SHOPFLOOR was an industrial internet of things application used in the production department.

SHOPFLOOR exemplifies software used in the production process to facilitate the flow of information between different machines, people, and processes. Currently, we learnt, different ideas were tested such as using sensor chips but so far, they have not really been adopted and made it beyond pilot use cases.

TIME had a specific use as a complement of LIN. It was kept in place in LIN's ecosystem as long as LIN was important to the organization. Yet, we did not see strong reasons why the system could not have been replaced by another system.

With knowledge of the level of embeddedness of the heavy applications within the infrastructure, the assessment revealed that embeddedness manifests in a duality of criticality and inertial propensities.

(Dis-)Continuance Analysis. Starting from system embeddedness, we realized from our investigation, that people talked about the inertia and criticality of highly embedded applications in the same breath. The striking finding is made salient by LIN that exemplifies the idea that inertia and criticality manifest simultaneously.

Our data suggest that both ANT and LIN exceeded their intended lifespan by several years. The MANUFACTURING firm was facing a legacy dilemma in which the applications stayed operational despite capability shortcomings and lack of flexibility, indicating the inertia manifestations.

Interestingly, the primary attribution for this was mainly since they had *become critical* for many of the company's operations. While the applications were still maintained and used in many subsidiaries as a critical component, interviewees simultaneously reported on lacking capabilities, high internal complexity, technical legacy issues, a stagnating user base, and the stepwise crowding out of innovation from the system.

Our analysis led us to two conclusions. First, we observed that a system's criticality and inertia increase with increasing system embeddedness. This increase continues until a point is reached when the impetus to discontinue the system becomes stalled by the weight of the inertia and criticality amassed over time, i.e., the system falls in a criticality trap. From a related but different viewpoint, we also observe a converse effect. With decreasing system embeddedness, a system's criticality and inertia decrease. Over time, such manifestation leads to a situation in which the system loses its importance and relevance within the digital infrastructure and becomes a candidate for discontinuance, i.e., the redundancy slip.

Table 3 shows evidence for the criticality trap. It illustrates that LIN and ANT were perceived as inappropriate for today's demands and stretched beyond their capacities, yet they are still in use (and growing); furthermore, the highlighted points reflect the underlying inertia and criticality manifestations of system embeddedness at work, plus how they lead toward a criticality trap.

Table 3: Evidence for a Criticality Trap

Criticality Trap in LIN
Core Criticality
"When I was talking to [the] CIO about LIN, he was like, he cannot understand how changing LIN is going to be...It's next to impossible. …according to him, … it's very central."
"…. We cannot change our LIN [system] for example, fast and agile. It would not happen. It would take two to three years and an [expletive] amount of money, so it's not going to be agile."
"The data structure is complicated that we end up doing double work in the planning of the team resourcing. That means once the resources are scheduled roughly in LIN, we still end up scheduling in Excel or MS-Project again."
Importance
"The mechanical department uses a 3D modeling software which is connected to LIN. So, if LIN is not working then they can go home."

'But LIN is in my opinion very limited [in resourcing and team planning] because it´s not easy to find out which of the team members are available. It cannot be used with several people at the same time because the last guy who saves, overwrites all others. And you know we are living in 2017 and not 1990s. So that´s a little bit disappointing."
Reluctance reasons
'Replacing LIN with something that's more kind of modern and easier to maintain and more effective means that we should change our ways of work accordingly. And that's the biggest thing actually."
'LIN is not that crappy, but it's pretty crappy. And the difficulty of that is that it's so integrated to our ways of working and the processes …"
'So, LIN is not that nice to use. It is what it is, but you know that's [laughs] just life in a sense."
'Does it count if you always have like 50 things on your task list that doesn't get any shorter? … sorry, my head is so full that I can't get more information in because it's so occupied all the time... So, now I have to start thinking, oh yeah, by the way, next month we should start learning SharePoint… because we are experimenting and searching for [new] things. I am like working 150% already."
Criticality Trap in ANT
'ANT is basically the side server ... [LIN is] a separate server but they´re using things that talk to each other. So, they are getting to be a bit more integrated [into LIN]"
'[ANT] was the old ERP system and is still used [in] the accounting financial department side."

Table 4 shows evidence for the redundancy slip. Redundancy slip can occur when the need for change results in a corresponding impetus to change with relatively little inertia against such change. It should be noted, however, that the notion of criticality and redundancy results from the relative importance (heaviness/lightness) of the system to be changed. A less important system is likely to become redundant over time.

Table 4: Evidence for Redundancy Slip

Redundancy Slip in Shopfloor IT
'Interviewer: Shopfloor IT. How well are they integrated. Interviewee: "not as well ... should be much better"
'ICT [should be] more involved in the manufacturing."
'Communication between the individual systems [in production] still needs to be facilitated or improved somewhere"

In summary, the qualitative analysis reveals both the criticality trap and redundancy slip as consequences of patterns of application growth or decline.

5. Discussion

Principal Results: Using case study data from two firms, we, firstly, find evidence supporting a Matthew effect in system embeddedness. Our analysis of a primary case (MEDIA) indicates that a polynomial model of growth in system embeddedness explained by system embeddedness in prior periods fits the data best. This suggests that the slogan *"For to everyone who has will more be given, and he will have abundance; but from him who has not, even what he has will be taken away"* (Matthew 25:29, RSV) plays an important role in the growth of system embeddedness. Our model outlines both the increasing embeddedness of heavily integrated systems and the stagnating or decreasing embeddedness of lightly embedded systems. We replicate this result qualitatively in our second case (MANUFACTURING).

Secondly, our paper further makes the connection between systems *"that have and will more be given"* to the criticality trap. With knowledge of the level of embeddedness of the systems, the analysis revealed that embeddedness manifests in a duality of criticality and inertial propensities. This increase continues until a point is reached when the impetus to discontinue the system becomes stalled by the weight of the inertia and criticality amassed over time. This point might be perceived too late because of the accumulated and self-reinforcing growth is underestimated. Consequently, even if a system's integrations are known and fully understood, the level of technical and semantic interlock and functional integration among systems is often so high that replacement costs appear to exceed the potential benefits.

Thirdly, our paper connects the systems *"that have not and even what they have will be taken away"* to the redundancy slip. With the knowledge that systems stagnate or lose connections, we observed increased discontinuance of these systems, despite their potential continued value to the business. Additionally, we observed that even growing light systems, those temporarily intensifying in connections, may also be decommissioned, possibly due to the "intensifying to cease" effect where systems experience a final burst of activity before discontinuance (Rezazade Mehrizi et al., 2019).

Comparison with Prior Work: This new evidence confirms suspicions of a Matthew effect (Fürstenau et al., 2019) using time-series panel data from a longitudinal case. This study presents an

advancement of the original survey data by Furneaux & Wade (2011, p. 586) by adopting an alternative approach grounded in real-world company data. Furthermore, the findings are in line with recent research that finds that large, embedded, and old systems are difficult to replace, while light, young systems may be ceased (Rezazade Mehrizi et al., 2019; Rinta-Kahila et al., 2023; Soliman & Rinta-Kahila, 2020). Following the logic of self-reinforcing growth (Henfridsson & Bygstad, 2013), when a system gains importance and critical traction, there are usually good and noble reasons to continue down this path (Sydow et al., 2009). However, the responsibility would lie in the hands of the digital infrastructure decision makers to consider the future implications of yielding to the eventuality of a criticality trap. It is thus necessary for researchers and practitioners to further understand the relationship between avoiding inertia and leveraging criticality. In this regard, we elaborate on the "dual, paradoxical nature" of system embeddedness in a digital infrastructure as something that promotes change and rigidity (Ciborra, 2000; Hanseth & Rodon Modol, 2021; Star & Ruhleder, 1996; Wimelius et al., 2021). This is akin to understanding the balance between taking advantage of innovations in IT and having a "good enough" system (Soliman & Tuunainen, 2022).

Methodologically, we offer an alternative way of assessing the Matthew effect, thus responding to prior methodological works on the subject (Perc, 2014). While the Matthew effect has often been analyzed by fitting an exponential function, this approach is limited when the empirical data spans multiple decades. Additionally, the exponential function allows for limited observations of redundancy slips, whereas our analysis provides a more in-depth examination of these phenomena.

Limitations: Being limited to the media and manufacturing sectors, this study lacks full generalizability across all industries and organizational contexts, partly due to the methodological constraints, such as the shorter observation period and qualitative data sampling in the MANUFACTURING case. While we have concentrated on the Matthew effect, it is important to acknowledge other factors, such as technological advancements and organizational responses to security issues, that also contribute to changes in system embeddedness.

Conclusions: We believe managers can benefit from this framework that allows for assessing system embeddedness in a meaningful and practically applicable format. In light of increasing cases of disruptive innovations that require significant changes or overhauling of an organizational setup, the burden of a hard-to-replace system could have significant consequences. This happens because companies often lack transparency about the hidden structure (Baldwin et al., 2014) of their digital infrastructure slowing down replacement decisions as risks remain poorly understood or causing intensified efforts to cease (Rezazade Mehrizi et al., 2019).

By using network analysis as we do in our paper, complex, hidden structures can be uncovered. Based on this, managers may focus on heavy systems in their transformation and replacement planning, because information systems that have reached a critical size and risk status are more critical and harder to replace. The assessment framework should be useful both practically and theoretically, enhancing understanding of system migrations, carve-outs, restructurings, and system consolidations in IT cost-cutting contexts, and in mergers and acquisitions and other enterprise transformation projects.

An area of research opened by this paper is a prescriptive study that presents managers with possible solution paths on what to do after identifying the level of system embeddedness in the infrastructure setup of their organizations. The initial step, assessing and identifying the areas where an organization's infrastructure might be plagued by inertia, is highly relevant. However, notably for practitioners, it is of vital importance to understand how to overcome the challenges of system embeddedness and the associated consequence of criticality trap and redundancy slip. Applying the analysis presented in this paper is expected to provide scholars and managers with a vivid assessment of system embeddedness and the pertinent considerations to avoid falling into the criticality trap or redundancy slip. Future research could also explore the boundaries and exceptions to the Matthew effect to better equip organizers in navigating and avoiding the associated risks and challenges.

In conclusion, system embeddedness can be seen as a double-edged sword. Too much embeddedness can lead to criticality trap, where an organization can feel stuck with a system that is simultaneously crucial in some areas and useless in others. Yet, too little embeddedness can lead to a redundancy slip, where investments in new innovations are lost because they did not get sufficiently embedded to gain traction in the organization. This makes the Matthew effect a powerful mechanism driving the evolution of systems and entire digital infrastructures.

References

Akbari, K., Fürstenau, D., & Winkler, T. J. (2024). Governance and Longevity of Architecturally Embedded

Applications. *Journal of Management Information Systems*, *41*(1), 266–296.
Baiyere, A., & Hukal, P. (2020). *Digital Disruption: A Conceptual Clarification*. Hawaii International Conference on System Sciences.
Baldwin, C., MacCormack, A., & Rusnak, J. (2014). Hidden structure: Using network methods to map system architecture. *Research Policy*, *43*(8), 1381–1397.
Christensen, C., & Overdorf, M. (2000). Meeting the Challenge of Disruptive Change. *Harvard Business Review*, *78*, 67–76.
Ciborra, C. U. (Ed.). (2000). *From control to drift: The dynamics of corporate information infastructures*. Univ. Press.
Dreyfus, D., & Iyer, B. (2008). Managing architectural emergence: A conceptual model and simulation. *Decision Support Systems*, *46*(1), 115–127.
Furneaux, B., & Wade, M. (2011). An exploration of organizational level information systems discontinuance intentions. *MIS Quarterly*, *35*(3), 573–598.
Fürstenau, D., Baiyere, A., & Kliewer, N. (2019). A dynamic model of embeddedness in digital infrastructures. *Information Systems Research*, *30*(4), 1319–1342.
Granovetter, M. (1985). Economic Action and Social Structure: The Problem of Embeddedness. *American Journal of Sociology*, *91*(3), 481–510.
Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: The case of building internet. *Journal of Information Technology*, *25*(1), 1–19.
Hanseth, O., & Rodon Modol, J. (2021). The dynamics of architecture-governance configurations: An assemblage theory approach. *Journal of the Association for Information Systems*, *22*(1), 130–155.
Henfridsson, O., & Bygstad, B. (2013). The Generative Mechanisms of Digital Infrastructure Evolution. *MIS Quarterly*, *37*(3), 907–931.
Lagerström, R., Baldwin, C., MacCormack, A., & Dreyfus, D. (2014). Visualizing and measuring software portfolio architecture: A flexibility analysis. *16th International Dependency and Structure Modelling Conference, DSM 2014*, 65–74.
MacCormack, A., Lagerstrom, R., Dreyfus, D., & Baldwin, C. Y. (2016). *Building the Agile Enterprise: IT Architecture , Modularity and the Cost of IT Change*.
Matyszczyk, C. (2021, February 21). Microsoft Teams or Zoom? A salesman offers his stunning verdict. *ZDNET*. https://www.zdnet.com/article/microsoft-teams-or-zoom-a-salesman-offers-his-stunning-verdict/
Mayring, P. (2019). Qualitative Inhaltsanalyse – Abgrenzungen, Spielarten, Weiterentwicklungen. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *Vol 20*(3), No 3 (2019): Qualitative Content Analysis I.
Merton, R. K. (1968). The Matthew Effect in Science. *Science*, *159*(3810), 56–63.
Ostertagová, E. (2012). Modelling using Polynomial Regression. *Procedia Engineering*, *48*, 500–506.
Pipek, V., & Wulf, V. (2009). Infrastructuring: Toward an Integrated Perspective on the Design and Use of Information Technology. *Journal of the Association for Information Systems*, *10*(5), 447–473.
Rezazade Mehrizi, M. H., Rodon Modol, J., & Zafar Nezhad, M. (2019). Intensifying to cease: Unpacking the process of information systems discontinuance. *MIS Quarterly*, *43*(1), 141–165.
Rinta-Kahila, T., Penttinen, E., & Lyytinen, K. (2023). Getting trapped in technical debt: Sociotechnical analysis of a legacy system's replacement. *MIS Quarterly*, *47*(1), 1–32.
Soliman, W., & Rinta-Kahila, T. (2020). Toward a refined conceptualization of IS discontinuance: Reflection on the past and a way forward. *Information and Management*, *57*(2), 103167.
Soliman, W., & Tuunainen, V. K. (2022). A tale of two frames: Exploring the role of framing in the use discontinuance of volitionally adopted technology. *Information Systems Journal*, *32*(3), 473–519.
Star, S. L., & Ruhleder, K. (1996). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research*, *7*(1), 111–134.
Sydow, J., Schreyögg, G., & Koch, J. (2009). Organizational Path Dependence: Opening the Black Box. *Academy of Management Review*, *34*(4), 689–709.
Tiwana, A., & Safadi, H. (2024). Atrophy in Aging Systems: Evidence, Dynamics, and Antidote. *Information Systems Research*, *35*(1), 66–86.
Vaast, E., & Walsham, G. (2009). Trans-Situated Learning: Supporting a Network of Practice with an Information Infrastructure. *Information Systems Research*, *20*(4), 547–564.
Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications*. Cambridge University Press.
Wilks, S. S. (1938). The Large-Sample Distribution of the Likelihood Ratio for Testing Composite Hypotheses. *The Annals of Mathematical Statistics*, *9*(1), 60–62.
Williams, R., & Pollock, N. (2012). Moving Beyond the Single Site Implementation Study: How (and Why) We Should Study the Biography of Packaged Enterprise Solutions. *Information Systems Research*, *23*(1), 1–22.
Wimelius, H., Mathiassen, L., Holmström, J., & Keil, M. (2021). A paradoxical perspective on technology renewal in digital transformation. *Information Systems Journal*, *31*(1), 198–225.
Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data* (2nd ed). MIT Press.
Yegorov, Y., Wirl, F., Grass, D., Eigruber, M., & Feichtinger, G. (2022). On the matthew effect on individual investments in skills in arts, sports and science. *Journal of Economic Behavior and Organization*, *196*, 178–199.
Yin, R. K. (2017). *Case study research and applications*. Sage Publications.

Appendix

The appendix for this study can be accessed at https://zenodo.org/doi/10.5281/zenodo.13825265.