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SYSTEM EMBEDDEDNESS AND CONTINUANCE INERTIA: AN EXPLORATORY NETWORK ANALYSIS

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ABSTRACT

We suggest a method to assess the extent to which information systems in organizations show continuance inertia in a network of information systems linked through flows of information. Using centrality measures from network analysis, we argue that systems showing high degree centrality are likely to exhibit significant continuance inertia as they interface with many other systems and will most probably embed in a multitude of business processes. We argue that systems with high betweeness will also display serious continuance inertia as these systems act as a gateway and span between different parts of the information system network. We demonstrate and evaluate our method using a network data set from a German recycling company with close to thirty subsidies. The data compromise applications, information flows and ownership attributes. We find that network representations and centrality measures demonstrate practical value for the company's architects and IT managers to evaluate system embeddedness and inertial tendencies. Our paper stimulates further research on network-theoretic models to examine complex infrastructural arrangements.

KEYWORDS

System Embeddedness, Continuance Inertia, Network-Theoretic Models, Application Landscapes

1. INTRODUCTION AND MOTIVATION

IT infrastructures in organizations reflect decades of investments in hundreds or thousands of information systems by various actors (cf. Ciborra et al. 2000; Henningsson and Hanseth 2011). We position the research in a stream of work that addresses how to study, make sense, and intervene in such complex infrastructural arrangements (cf. Hanseth and Lyytinen 2004).

IS research focused largely on single systems – their design, implementation and use – in single sites (cf. Williams and Pollock 2012). A single systems view, however, downplays a system's embeddedness in a larger architectural context with respect to its technical integration with other systems as well as its use in different processes, units, regions and so forth. This is important as strong embeddedness often results in delayed or suspended discontinuance decisions (continuance inertia) where systems stay in use despite capability shortcomings or a lacking responsiveness to business initiatives (cf. Furneaux and Wade 2011).

We suggest network analysis as a perspective to understand the link between system embeddedness and continuance inertia. Our central theme is that a system's embeddedness depends on its position in a network with other IS-architectural artifacts. We argue that strongly embedded systems are likely to show excessive inertia as they interface with many systems, embed in several work practices and provide services for various organizational units. We construct a method for IT managers and architects to assess the extent of system embeddedness. Our method aims to support consolidation decisions of architects and IT managers in medium to large enterprises.

We proceed as follows: First, we link system embeddedness and continuance inertia (sec.2). Then, we present our approach: We conceptualize application landscapes as networks and treat those networks by certain techniques (sec.3). Next, we introduce the research context – the case of Recycle Inc. – and demonstrate the method's application there (sec.4). Finally, we discuss findings (sec.5) and directions (sec.6).

2. LINKING SYSTEM EMBEDDEDNESS AND CONTINUANCE INERTIA

Inertia denotes the "power of resisting by which every body, as much as in it lies, endeavors to preserve its present state" (Newton 1846:72). IS/IT strategy/organization research discusses various sources of inertia in complex infrastructural arrangements.

One class of models discusses inertia from a human agency perspective (cf. Robey and Boudreau 1999; Boudreau and Robey 2005). According to this view, actors resist new technologies as they fear changes in work practices or power structures. Explanations arise from culture (cf. Cooper 1994), politics (cf. Markus 1983), institutionalization (cf. Orlikowski 1992; Orlikowski and Barley 2001; Orlikowski 2007) or organizational learning (cf. Robey and Boudreau 1999). Orlikowski (2000) for instance observes limited groupware use by users reinforcing and preserving the status quo. Similarly, Boudreau and Robey (2005) find users initially avoiding a new ERP system as much as possible. Volkoff et al. (2007) portrays ordering routines becoming inscribed in an ERP system. Markus et al. (2000) note many of the problems firms experience in later phases of an ERP life cycle originating earlier but remained unnoticed or uncorrected. Leonardi (2011) finds path dependence studying engineers' use of simulation tools: Changes in technologies make particular complementary changes of work routines more beneficial, and vis-versa.

Another class of models discusses excess inertia from an installed base perspective (cf. David and Greenstein 1990). According to this view, technologies having reached a certain size of adopters become hard to abandon due to switching costs or coordination problems (cf. Ciborra et al. 2000; Hanseth and Lyytinen 2004). Hence, often no actor is willing to bear the risk of being the first standard adopter (cf. Weitzel et al. 2006). Zhu et al. (2006) show excess inertia for firms migrating from EDI to open internet standards.

A third class of models, closest to our thinking, discusses inertia from an IS architectural viewpoint (cf. Ross et al. 2006). According to this view, complexity – arising from a system's interactions in highly distributed environments – often inhibits change (cf. Schneberger and McLean 2003). Ross et al. (2006) – in their book on enterprise architectures – for instance portray an investment bank whose legacy systems were cobbled together so intensively that "it was a miracle they worked" (ibid:11). The complex architecture created rigidities and excessive costs as systems had to be adapted manually to respond to each new business initiative. An IS architectural viewpoint hence constructs inertia to depend on the extent of interactions.

We draw on Furneaux and Wade's (2011) observation that a system's embeddedness in an organization is a source of continuance inertia. According to this view, the "extend to which the use of information systems is part of organizational activity (…) impose significant constraints on discontinuance intentions" (ibid:579). One implication is that, as suggested by the IS architectural viewpoint, embeddedness is determined by a system's position in the IS architecture. More precisely, the extent of embeddedness will be formed along several dimensions. Furneaux and Wade (2011) point to a system's embeddedness in work practices and the dependency of a system on other systems on the technical level. Regarding the latter, a survey among IT managers found that systems being integrated more strongly became replaced less frequently (ibid:590).

Empirical studies let us believe that a system's embeddedness, as we have defined it, affects continuance inertia. A number of methods support IT managers and architects in tasks related to assessing a system's embeddedness. Examples, from an IS architectural viewpoint, are Aier and Winter (2009), Buckl et al. (2009), Lankhorst (2009) and Schütz et al. (2013). Most of these methods draw on an engineering approach. We suggest a different approach using network analysis as a starting point (cf. Wasserman and Faust 1994; Jackson 2008). We particularly believe that network analysis offers extraordinary potentials to assess system embeddedness as we can build on relationship measures that will help to overcome the single systems view (see section 1). Using a design-science approach (Peffers et al. 2007), we suggest a method that addresses the following problems relevant for IT managers and architects:

1. What concepts from network analysis are helpful in assessing IS architectures in terms of embeddedness?
2. How will embeddedness affect an organization's ability to discontinue information systems?

3. METHOD DEVELOPMENT

We suggest modeling an organization's application landscape as a network *N(g)* consisting of *n* nodes and *m* links between these nodes. Nodes denote applications – an SAP finance module as well as a MS Access-based controlling cockpit. Different types of associations connect applications. We find information flows most appropriate for our study as they approximate well technical integration among applications, which was one of Furneaux and Wade's (2011) core dimensions of embeddedness. Our network is undirected because we do not consider information flow directions as poor data quality often prevents meaningful interpretation. The network is unimodal (cf. Jackson 2008) as it compromises only one node type (applications).

Next, we suggest techniques to evaluate IS network structures: Centrality measures characterize a single node's embeddedness and density, degree distribution, clustering coefficient and path length describe a network's macro state. To begin, centrality measures enable to compare nodes and to say something about a node's position in relation to the overall network (Jackson 2008:37). Centrality measures can be grouped in four categories (cf. Jackson 2008:37):

1. degree – how connected is a node
2. closeness – how easily can a node reach other nodes
3. betweeness – how important is a node in terms of connecting other nodes
4. neighborhood characteristics – how important, central or influential is a node's neighborhood

To assess system embeddedness, we suggest using degree and betweeness centrality. *Degree centrality* simply keeps track of the degree of a given node. A node with degree $n – 1$ would be connected to all other nodes, and therefore be quite central to the network (cf. Jackson 2008:38). The degree centrality of a node is $d_i(g)/(n – 1)$ where $d_i(g)$ denotes the degree of a given node *i* and *n* the total number of nodes in the network *N(g)*. In our case, degree centrality refers to the number of applications a given application interfaces with compared to the total number of applications. This measure is comprehensible and serves as a useful starting point to assess system embeddedness. However, degree centrality misses many interesting aspects of a network. In particular, it does not capture how well located a node is (cf. Jackson 2008:38). It might be that a node has relatively few links but lies in a critical location of a network (ibid:38). *Betweeness centrality*, in contrast, is based on how well a node is situated in terms of the number of shortest path *k* to *j* that *i* lies on (Jackson 2008:39). Betweeness centrality delivers advanced information as it aptly captures the degree to which an application connects different areas of the application landscape; high betweeness thus points to increased risks for the overall network to collapse if a given application fails.

The next types of measures characterize a network's macro state. Density is used in social and economic networks to assess the degree of connectedness, where it is written as proportion of possible links that are actually present in the graph (Wasserman and Faust 1994:101). If a network has a low density then typically it consists only of small components, but if the density is high enough then a single large component forms, usually accompanied by many separate small ones (Newman 2011). Applied to information system networks, a high density implies strong levels of application integration. As application costs (per module) and costs to interface trade off (cf. Schneberger and McLean 2003), firms will be sensitive balancing the number of applications and the efforts to integrate them. In other words, high density points to strong integration but trades off with high costs to interface. One may think of different integration patterns as enterprise application integration (EAI) or service-oriented architectures (cf. Erl 2006).

Applying the concept of degree is straightforward. The average degree gives a rough estimate of nodes' connectedness (cf. Jackson 2008:59). The degree distribution – a plot of the count of links for particular nodes – describes the network more comprehensive (ibid.). By examining empirical degree distributions, one could also identify mathematical distributions (e.g. Poisson or scale-free) to approximate the network. In this context, assortativity (Newman 2002) indicates the extent to which high-degree nodes tend to connect to other high-degree nodes (Jackson 2008:65). In itself, density and degree distribution are still limited. Hence, we also describe the network structure by the clustering coefficient. The average clustering coefficient is defined as the mean over all local clustering coefficients which are designated as the number of pairs of neighbors of *i* that are connected divided by the overall number of pairs of *i (*cf. Watts and Strogatz 1998).

4. DEMONSTRATION AND EVALUATION: THE RECYCLE INC. CASE

We demonstrate our approach using a case method (Yin 2009) in a German recycling company. Case studies are a valid method to evaluate design science artifacts (Hevner et al. 2004:86). Recycling Inc. employs approximately 9,000 people and its main business areas are waste operations, recyclables trading, services, steel and metals recycling. Our contact point was one IT unit in the waste operations domain employing – at the time of our research – 15 people. We accessed a comprehensive data set from the company's IT architecture group – gathered during a requirements engineering project in 2011. The data compromised the as-is application landscape, information flows and business processes. The "IT master plan" held business process supports for 28 subsidiaries and the core waste operations process included three main steps:

(i) Distributing and pricing waste management services (e.g. different quality containers),
(ii) Operating and disposing waste including tour planning & weighting and
(iii) Invoicing, accounting and controlling services

We expected the data to reflect that process but we were surprised by the variety of different applications and their complex integration. The observed fragmentation led us to perform additional analyses on the link between system embeddedness and continuance inertia.

The unadjusted data set included 450 application components, 270 information flows, 73 business processes and several thousand business IT supports. After initial data cleansing, we proceeded with 212 nodes (applications) and 234 links (information flows). The data included three additional application attributes – technical support, ownership, and user – and three interface attributes (status, transferred data and interface type). Additionally, we conducted thirteen interviews with domain IT and business experts to get an in-depth understanding. We met with stakeholders of Recycle Inc. to present and discuss the findings. The responsible IT manager appreciated our results and it has informed CIO-level decision making.

4.1 Macro Structure of Recycle Inc.'s Information System Network

Table 1 describes the macro structure of the information system network. Network density is 0.010 and average degree is 1.245, indicating a sparse network with one giant component (cf. Figure 1A).

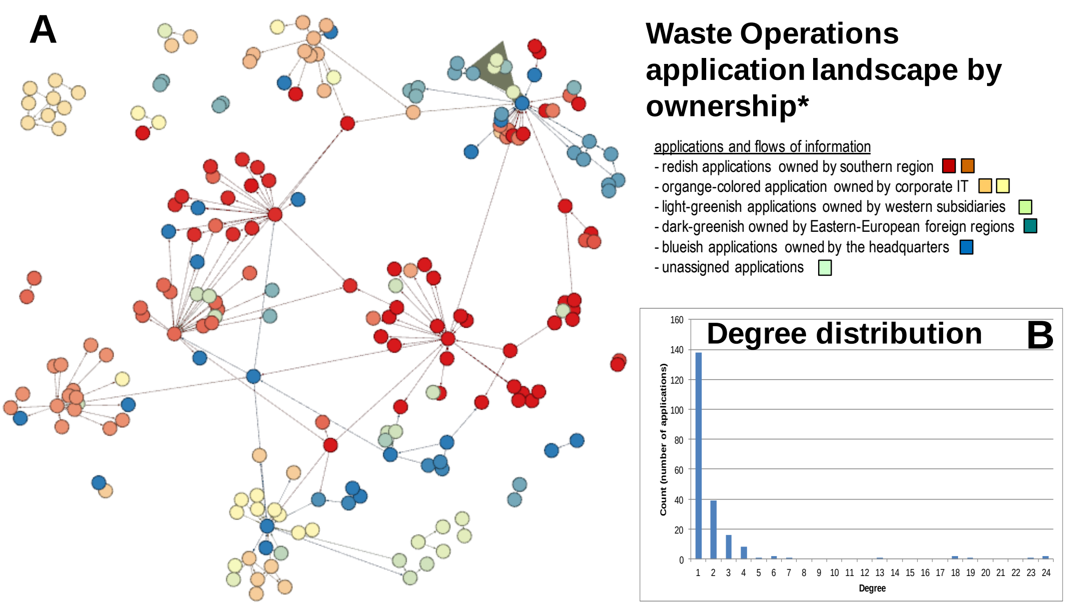

Figure 1. Recycle Inc's. information system network: Nodes (applications) and links (information flows). One may think of a node as a SAP finance module. Colors depict application ownership, headquarter-owned ones are for instance blue

As the network is loose and has several components, average clustering coefficient is reported for the giant component: Clustering coefficient is 0.241. Figure 1B shows the network's degree distribution. We find many applications with one or two interfaces while there are only few with more than five interfaces. In connection with Figure 1A, we conclude that Recycle Inc.'s IS network tends towards a hub-and-spoke structure: Few important applications ("hubs") are surrounded by several small components ("spokes").

Table 1. Descriptive statistics of Recycle Inc.'s information systems network

Network Structure			Degree		Clustering	Path Length
Number of nodes	Number of edges	Density	Average degree	Assorta-tivity	Average clustering coefficient	Average Path Length
212	234	0.010	1.245	-0.0096	0.241 (15 triangles)	4.357

4.2 Recycle Inc.: System Embeddedness and Continuance Inertia

We move forward by presenting results on degree and betweeness centrality. We begin by walking through the left side of Figure 2 depicting degree centralities. Central systems are colored in blue, red and orange; less central applications appear turquoise and green. Figure 2A lists the most central applications: SAP FiCo, RANO, Enwas, BetaIS and Candy, of which SAP FiCo – a finance and accounting application – and RANO – an ERP/logistics system – are most important for our theorizing.

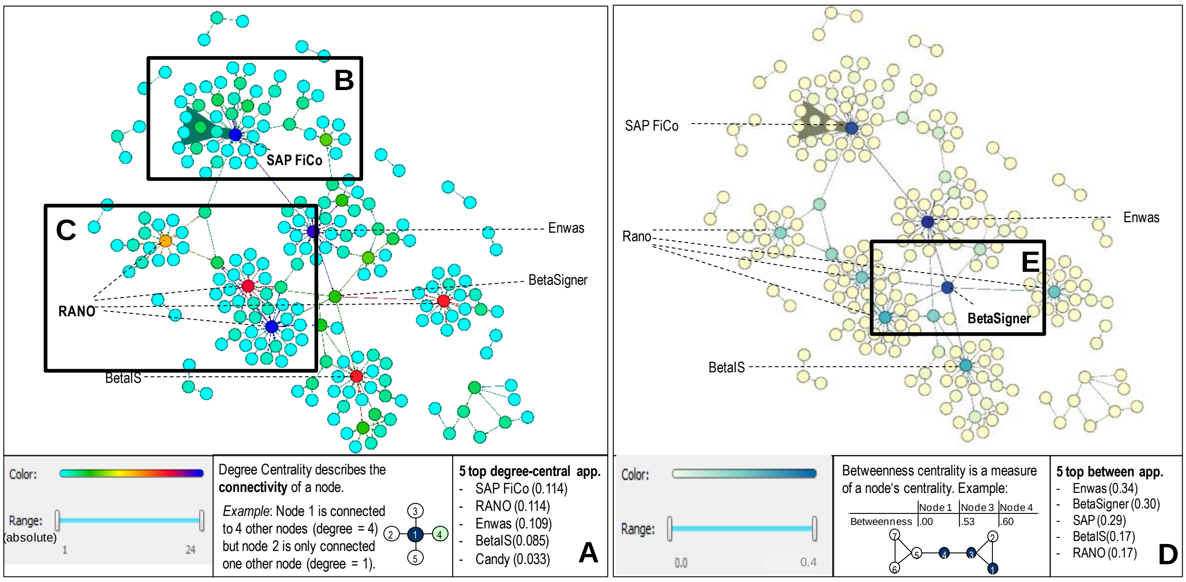

Figure 2. Degree (left) and betweeness centrality (right) in Recycle Inc.'s information system network

SAP FiCo, depicted in Figure 2B, is the most central system by the total number of interfaces (24 interfaces absolute). Consider in this connection the waste operations process: SAP is used mainly for invoicing and accounting. Still, numerous transactional systems provide data for SAP, e.g. several ERP/logistics systems, weighting and tour planning programs; this makes the system an important data consumer. Furthermore, many applications use data from SAP, e.g. a controlling cockpit, a data warehouse and several archival systems. Altogether, the system's high degree approximates well the perception that emerged in our interviews: The system is strongly embedded in Recycle Inc.'s organizational activity. Interviewees reported Recycle Inc. had not updated SAP from R/3 for a long time; we believe this fact shows the company's dependence on the business-critical yet strongly customized system indicating continuance inertia.

We turn to RANO as a second example. RANO, depicted in Figure 2C, is interesting: Several instances exist, each blueish or reddish. Each of the system's different installations forms an own ecosystem with a RANO instance as a hub and further satellite applications. Satellites are often small programs supporting tour planning, weighting, reporting or acting as a dashboard. RANO entered Recycle Inc.'s application landscape when the company acquired a large competitor in Germany's southern region. Recycle Inc. had not yet consolidated different RANO instances into a central business solution, which was expected to save costs but also to cause a major restructuring and to become resisted within subsidiaries.

Figure 2D shows betweeness centralities. Rankings of degree and betweeness centrality differ. BetaSigner – a reporting tool in the area of dangerous goods – for instance is prominent in betweeness, but has not been figured centrally by degree. The data show that BetaSigner, depicted in Figure 2E, bridges between different parts of the application landscape. While the system was originally intended to act as a read-only data aggregator, without major writing and updating functions, its central position let BetaSigner more and more become a gateway connecting systems from different regions. Since it was introduced in 2008, it constantly grew towards a middleware exchanging messages among ERP installations in different regions.

5. DISCUSSION

5.1 Applying Network Analysis to Information System Networks

When we compare the observed network to a random network, our results suggest that information system networks are not purely random networks. In a network with 212 nodes, we observed an average degree of 1.245 (cf. Table 1). Following Jackson (2008:59), a purely random network with this average degree would have a probability of any given link forming of 1.245 / 232, or roughly 0.005872. The clustering we observed in the actual network was 0.241 which is approximately 44.9 times greater than what we would see in a random network with the same size and connectivity. We thus propose for further research:

Proposition 1: *Information system networks are non-random networks.*

Assortativity denotes that high-degree nodes tend to connect to other high-degree nodes (cf. section 3). Newman (2002) claims that technological networks often show a negative assortativity (cf. Jackson 2008:66). We do not observe assortative mixing in the data (assortativity degree: -0.0096). A possible explanation for this lack of correlation among high-degree nodes is the specific network formation process in IS networks: Low-degree nodes ("small programs") often attach to only one high-degree node. These high-degree nodes in turn connect to many low-degree nodes as well as other high-degree nodes balancing the correlations between low and high-degree nodes. Our network representation (cf. Figure 1) also points in this direction of islands of shared technology: Five to six high-degree applications, e.g. SAP (cf. Figure 2B), are best characterized as hubs complemented by many spokes. Thus, we suggest:

Proposition 2: *Information system networks form hub-and-spoke networks.*

5.2 System Embeddedness and Continuance Inertia

Furneaux and Wade (2011) link system embeddedness and continuance inertia. We suggested a method to assess the extent of system embeddedness drawing on measures from network analysis. We identified most central systems in Recycle Inc.'s IS architecture with respect to degree and betweeness centrality. We found that degree is a straightforward measure that can easily be applied and communicated to stakeholders; a high degree points to important systems being surrounded by a large ecosystem of satellites. We gave the examples of SAP FiCo (cf. Figure 2B) and RANO (Figure 2C) to illuminate why a high degree is often associated with continuance inertia. Additionally, betweeness centrality highlights systems spanning between different parts of the landscape. We discussed the example of BetaSigner (Figure 2E) to show that such system are often important gateways. Altogether, we found that both measures complement each other.

6. CONCLUDING REMARKS

This study explored what concepts from network analysis are helpful in assessing IS architectures with respect to system embeddedness. We also aimed to shed light on reasons why system embeddedness affects continuance inertia. To achieve this, we suggested a method that conceptualizes system embeddedness as the extent of connectedness in a network of applications and flows of information. To assess system embeddedness, we used centrality measures from network analysis. We found that degree centrality is a simple and yet powerful measure that captures the number of direct neighbors of a system. When a system shows a high degree, it is likely to exhibit specific inertia as illustrated in the example of SAP FiCO (cf. Figure 2B): Organizations delay suspensions or updates as a large number of interfaces had to be adapted, some of which may be undocumented or idiosyncratic. Changes would ripple and require the adaptation of several other business-critical systems. Additionally, betweeness centrality captures a system's position as a boundary spanner. Systems with high betweeness centrality will also be critical with respect to continuance decisions as shown in the example of BetaSigner (cf. Figure 2D): They connect different clusters of an application landscape. In case of their discontinuance the architecture is at risk to break down, so they may stay operational despite capability shortcomings. Altogether, our primary contribution has hence been to demonstrate possible measures to assess a system's embeddedness.

Our work is not without limitations. First, we focused on the technical integration between information systems as one important dimension of embeddedness (cf. Furneaux and Wade 2011). Further work is necessary to operationalize the embeddedness of systems in organizational work practices. A possible starting point provides work by Aier and Winter (2009) on business and IT architecture linkages. Second, although we could observe legacy traces in our data, we could not track historical growth processes over time. Incorporating network dynamics would be a natural next step. This could be done by gathering further network data at different points in time. Additionally, a simulation study that fits the network dynamics with empirical data could be performed; it could improve our understanding of generative mechanisms constituting real information system networks. This presents interesting challenges for future research.

Turning in conclusion to managerial implications, we believe that IT managers can benefit from concentrating on *central* systems in their analysis of system embeddedness and continuance inertia. Information systems having reached a critical size and risk status will be more likely to exhibit continuance inertia. Systems playing a central role in the IS architecture are also more likely to be essential in multiple business processes. In this connection, our approach provides IT managers a standardized procedure to assess system embeddedness in the context of complex infrastructural arrangements.

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