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Theory Foundations for Enterprise Architecture Management: Insights from Infrastructure-Related Economics

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Abstract
Enterprise Architecture Management (EAM) is a highly relevant topic in organizational practice and design science research. However, the constant need for investigating EAM's benefits and for justifying its costs has not satisfactorily been dealt with. Traditional business case based justifications fall short in considering the cross-project, cross-unit, and enterprise wide character of EAM. Because of EAM's infrastructure-like nature, we survey economic theory for approaches explaining cost and benefit effects of EAM and to discuss their potential to derive implications for EAM design. The paper is a first attempt to bring together different bodies of knowledge in two diverse fields (IS and economics). Findings are theories that explain why infrastructure-like concepts are necessary and further hints for in-depth analysis that is supposed to lead to meaningful insights for EAM design. Based on the discussed economic theories, we compile a research agenda in the area of infrastructure-like systems.

Keywords: Enterprise Architecture Management, Economic Theory, Infrastructure, Design Theory, Theoretical Grounding

INTRODUCTION

Enterprise architecture (EA) describes the fundamental structures of an enterprise (e.g. company, government agency) in a business-to-IT view. Enterprise architecture management (EAM) is concerned with the establishment and coordinated development of EA in order to consistently respond to business and IT goals, opportunities, and necessities. As such, the notion of EAM goes beyond EA modeling and includes the management tasks of planning and controlling business and IT change from an enterprise-wide perspective (cf. e.g. The Open Group 2009).

EAM[1] has developed into an accepted practice in enterprises (Winter and Fischer 2007). During the recent decade, the development has strongly been driven by practitioners (e.g. the TOGAF Framework by the Open Group (2009)) and design oriented researchers (Mykhashchuk, Buckl, Dierl and Schweda 2011). However, discussions about the evaluation of EAM's effectiveness constantly arise. According to Slot, Dedene and Maes (2009), EAM is surprisingly often implemented without a business case or cost-benefit consideration at hand. Boucharas, van Steenbergen, Jansen and Brinkkemper (2010) describe the difficulties to establish a business case as a major problem impeding the introduction and development of EAM in enterprises. We consider these problems to be rooted in the nature of EAM. Since EAM has a holistic scope (Aier, Gleichauf and Winter 2011) and is focused on the entire enterprise rather than on single projects or business units, a case-based ex-ante evaluation seems not to be appropriate. Instead, a more holistic analysis of why and how EAM is implemented needs to be considered.

These questions are tightly coupled and might be addressed by an EAM design theory that supports practitioners in developing concrete EAM solutions (Goldkuhl 2004, Gregor and Jones 2007, Walls,

[1] In the following we use the broader term EAM to depict not only EA management, but also EA components.

Widmeyer and El Sawy 1992). A design theory according to Walls, Widmeyer and El Sawy (1992) is "a prescriptive theory based on theoretical underpinnings which says how a design process can be carried out in a way which is both effective and feasible". Such underpinnings can be derived by techniques like empirical grounding, internal grounding or theoretical grounding (Goldkuhl 2004). So far in the domain of EAM much work applying the first two techniques has been conducted. However, since the discussion about the business case of EAM still is in progress, we consider the third perspective in this article. Therefore we investigate the potential of theoretical grounding and finding suitable underlying theories (kernel theories) in economics in order to understand the design of cost effective EAM and provide a discussion of further research aspects.

We especially consider economic theory for two reasons: First, economics aims at explaining how offers and demands are coordinated and how benefits are realized (Krugman 2009). The scope is not on single business cases but rather on a holistic, economy-wide perspective. Second, economics has a rich base of theoretical background because of its long research history. However, since economic research provides a rich base of theories, which we need to reduce for the purpose of this paper, we do not apply general economic theories but use a proxy that economists conduct research on. Because of the reasonable suspicion (which we discuss in detail later on) to consider the concept of *infrastructure* as the proxy, we investigate further in that direction. Our goal for this paper is to present some first findings from this investigation and provide a detailed agenda for further research. Thus, we aim at answering the following research questions:

RQ1: What are differences and commonalities between and among EAM and infrastructure?

RQ2: Do economic theories on infrastructure provide understanding in order to develop EAM design theories?

RQ3: What are further necessary research steps and opportunities derived from economic theory in order to develop suitable design theories about EAM?

In order to answer the research questions, we first searched well-established economic journals (selected by considering the VHB-JOURQUAL Ranking) in order to create a first overview on infrastructure related research. In order to form more specific insights, we afterwards included journals, conference proceedings and text books into the process that explicitly deal with infrastructure and related topics. In addition, we conducted backward searches if sources seemed to be meaningful. We used publications from the EAM domain in order to discuss the similarities between infrastructure and EAM. In summary the search process is conducted semi-structured for the overall idea, but explorative for its details. Since the link between EAM and economic theory has not been elaborated so far, we consider an explorative approach at this stage of research to be adequate.

We structure the remainder of the paper as follows: We describe related work in the next section. We proceed by answering our first research question and thus explaining the link between EAM and infrastructure in section three. We present results concerning the second research question in section four and conclude with a discussion and answers to the third research question in section five.

Related Work

As EAM and information systems (IS) are connected topics, related work in the area of economics of IS is relevant for a first survey. Bakos and Kemerer (1992) identify relations between IS as such and economics. Links are existent in the fields of information economics, economics of supply, IS and organizational performance, industrial organization, institutional economics and macroeconomic impacts of IS.

For the purpose of this paper the two latter ones are of highest relevance. The discussion of the macroeconomic impact of IS was conducted approximately a decade ago. According to Thatcher and Oliver (2001) the results are spread all the way from negative to no measurable impact. Thus, the question of macroeconomic impact of IS remains difficult. Kleist (1998) uses economic theory as a foundation for measuring IS implementation success, noticing that "the economic theory framework adds a level of analytic strength to the extremes of the highly qualitative and often technologically dependent measures, and the accurate but often too difficult to capture quantitative measures". The idea is picked up again by Hirnle and Hess (2005) in order to assess IS investments with the help of principal agent theory. According to Mittal and Nault (2009), IS are widespread in the enterprise and thus their benefits are difficult to measure. This leads to a necessity not only to include direct effects (e.g. direct influence of IS on production) into economic functions but also indirect effects (e.g. influence on production by influencing other input factors). This problem is similar to measuring the benefits of EAM (Boucharas, van Steenbergen, Jansen and Brinkkemper 2010). Summarizing the results and discussions of the authors above, economic theories provide helpful insights into IS theory as much as the understanding and development of IS by providing formal explanations of effects in socio-technical systems that are otherwise described too much in detail or too abstract.

Economic theory is also applied to architectures similar to EAM: Asundi, Kazman and Klein (2001) provide a procedure on how to assess different architectural strategies and design alternatives. For that reason they formalize a calculation procedure for the costs and benefits of different scenarios. They further add different probabilities in order to provide decisions support for the different design alternatives and strategies. In a more recent approach from software engineering, Clements (2007) provides formalized cost calculations on software architecture—based on an approach that is used for production line development decisions. In this approach, adoption and development costs of a central resource base are compared to costs of developing unique software pieces or reusing elements from the central asset base. However, EAM differs from these architectures since it aims at establishing an enterprise-wide control. Therefore much more social aspects are involved than in the development of technical architectures.

In general we observe two different approaches in order to select economic theories that should be applied to the field of IS: Schmaltz and Bucher (2008) apply different economic theories as kernel theories on data warehouse construction. The authors also confirm that economic theory can provide valuable insights for the design of information systems. However, the authors do not discuss the selection process itself. Kumar (2004) discusses the value of IS infrastructure investments based on underlying economic theory of financial asset valuation by first identifying similarities between the two fields. As discussed in the introduction, we also use the latter approach in order to deal with economic theories.

So far there is no discussion of EAM based on economic theory. Furthermore, related approaches apply very holistic theoretical models rather than more specific theories, investigated by drawing reasonable analogies. We work towards closing this gap by the following discussion.

Analogies between EAM and Infrastructure

Some understand infrastructure in terms of taxonomies of goods like railways, roads, electricity grids that determine infrastructure (Fourie 2006), or include only physical assets important to economic functions (Grubesic and Matisziv 2008). In a broader understanding, infrastructure refers to facilities and services that are needed for the economic, political, and social functions of a society (Grubesic and Matisziv 2008). A more recent understanding considers infrastructures to be "complex technical, economic and political systems that provide essential services to society" (Finger, Groenewegen and Kuennecke 2005). A fourth way to define infrastructure is by defining characteristics something has to comply to when being labeled 'infrastructure', e.g. "publicness" or "capitalness" (Fourie 2006).

We follow the definition that understands infrastructure as a system that provides essential services to a society. The society in our case can be rather small, e.g. the employees or stakeholders of an enterprise. This definition helps to better transfer the phenomenon of infrastructure than definitions like the first ones, which provide enumerations only. We refer to planning and control of infrastructure projects and infrastructure maintenance as infrastructure management (IM). However, identifying characteristics like given in the fourth infrastructure definition is important for us – especially to discuss our analogy. In consequence, we need to discuss characteristics of infrastructure in terms of different dimensions. We further discuss the analogy with

EAM and the counterexample of a very specific production planning system.

Control: A major characteristic of infrastructure is its provision (Button 1998) or strong *regulation* by (usually) public bodies (Frischmann 2005, Krugman 2009). The governance of EAM is a topic relevant for senior management, e.g. the chief information officer (Lindström, Johnson, Johansson, Ekstedt and Simonsson 2006) even if the detailed implementation modes differ and many different stakeholders participate (Aier, Gleichauf and Winter 2011). Thus, infrastructure is dealt with on a high level from the point of view of society meanwhile EAM is dealt with on a high level from the point of view of an enterprise (thus, is a management task). A contrast would be e.g. a specific production-planning system (PPS) that is only used in a specific part of the enterprise by a limited amount of people. Such a system would not need top management attention and we would not consider it to be infrastructure.

Investment Motivation: Public sector investments in infrastructures are a necessity since market failure is presumed (Aschauer 1989). That means, the public body is involved because no private investor would offer infrastructure at all (at least not with the premise that it is usable for everyone). Such a problem also occurs with EAM since single project teams or departments are not willing to invest into artifacts that provide value to everyone in an enterprise. Such problems do not occur with the already mentioned PPS since here no value and investment are visibly connected.

Decision & Power Structure: The scope of EAM includes the "business-to-IT" stack of an enterprise either as a whole, together with partners or in parts (e.g. division, department) (The Open Group 2009). Both, the enterprise dealing with EAM and the public body dealing with infrastructure, include subsystems (regions or actors in case of the society, departments or projects in the case of the enterprise) where decisions are taken and control is exercised. For a PPS such power structure usually is not necessary.

Usage Rights: According to Rietveld & Bruinsma (1998), the 'public' character of infrastructure implies that all members of a community who wish to use the resources are allowed and enabled to do so (*non-excludability*). Further they should be served in a non-discriminatory manner (*open accessibility*). EAM usually is not seen as a single project but as an enterprise-wide continuous service. Its documentation and models are supposed to be accessible for everyone in need. However, there can be different EAMs for different purposes (Winter and Fischer 2007) like there can be different physical infrastructures like railways, roads, electricity grids. For a PPS these aspects are less relevant since the information provided is interesting only for a very specific group of experts.

Resource Rivalry: Infrastructure resources in general are sharable resources, even if some vary in their capacity. This differentiates non-rival (infinite capacity) resources from partially (non-)rival (finite but renewable capacity) resources (Frischmann 2005). EAM resources in general are non-rival resources. A certain model or principle can (and should be) used more than once, abrasion effects do not exist.

Costs: According to Flyvbjerg (2009), infrastructure projects come along with huge amounts of spending. EAM development also fosters significant costs for most enterprises that need to be balanced with the potential savings (Slot, Dedene and Maes 2009). However, the costs are clearly visible while the benefits are usually not. This aspect differs the infrastructure from the non-infrastructure since e.g. for the PPS the provided benefits are measurable and calculable.

Moment & Area of Benefit Realization: Infrastructure costs and benefits are usually not realized in the same area or at the same time (Seitz 1993). Meanwhile funding might be given by the state government, the benefits might only occur in one region. The same holds true for the time dimension—costs that occurred in present might be the foundation for positive e.g. productivity effects in future. We consider the investments in EAM to be similar. For single departments and projects the justification of spending might not be transparent. However, from the global perspective spending still can make sense. For a non-infrastructure system such problem does not occur since the sponsoring part of the enterprise will also primarily use the system and profit from the benefits.

Development: According to Neumann (2009), infrastructure is always developed in a planned fashion and the society has to take care that new infrastructure is built according to these plans (and not being contradicted by private investors). Such aspects refer to the meta-organization of EAM. In the ideal case, EAM is not just appearing at a certain point but is planned and thus governed. Many non-infrastructure systems are implemented on an ad-hoc basis and not planned in the long-term.

Granularity: Winter and Fischer (2007) state that the granularity of EAM should be 'broad' rather than 'deep': For multistep dependency analyses and holistic coverage of IT business alignment, it is much more useful to cover a large number of artifact types and their dependencies on an aggregated level than investigating too much detail. We can also see such intention when discussing physical infrastructures. The railway network covers different areas but not each single house or enterprise. The same is valid for roads or power grids, were each house owner has to take care for the last part of the connection to the public network. The discussed counterexample of a PPS is oriented rather 'deep' than 'broad' since it covers a very specific aspect of the enterprise.

In our first research question we asked about differences and commonalities between and among EAM and infrastructure. Summarizing the discussion above, we see a significant similarity between EAM and infrastructure (management). Taking this similarity as a foundation, we will further investigate on kernel theories and relevant questions in the next section.

Economic Theories for EAM

Productivity Effects of Infrastructure

The first important question that has been investigated widely in economic literature is how much productivity infrastructure fosters. Such theory assumes a production function of a single enterprise (or aggregated enterprises of a country, region, etc.) that explains an output by the combination of input factors (Krugman 2009). In macroeconomic models these input factors are usually labor and capital (Aschauer 1989). Infrastructure is included as an input factor into this production function (Aschauer 1989, Straub 2010). If we directly apply this theory to the domain of EAM, a possible production function could use the following input factors:

(1) $$Y_t = f(C_t, L_t, EAM_t)$$

In this equation, Y denotes the overall output of goods and services of the enterprises, C the used private (enterprises') capital, L the enterprises' labor capital, EAM the amount of EAM established in the enterprise. All values refer to a certain time period t. Time can be interpreted as an indicator for technical change and thus productivity increase (Seitz 1993) (more explicit constructs like an additional variable are also possible to indicate this change (Aschauer 1989)).

Some questions arise: First, what are the units that should be used? This question is not finally solved. While it is evident for private capital (monetary) or labor (time, monetary, amount), for the amount of infrastructure it is difficult to answer. Very often it is also measured in monetary units (Aschauer 1989) (called e.g. public capital). However, not all public spending of capital is exclusively related to infrastructure. Other possible indicators are e.g. the length of roads and railways (Canning and Pedroni 2004, Straub 2010). Concerning EAM, the problem is comparable—measuring only the capital invested in EAM does not provide hints about its usefulness or quality. Since the pure size (e.g. amount and size of models, etc.) is also not sufficient, quality indicators are needed. Thus, for an application of production theory to EAM, we need a quality indicator included into the production function. A possibility is weighting the invested EAM capital with a function q which further includes the EAM quality EAMQ:

(2) $$Y_t = f(C_t, L_t, q_t(EAM_t, EAMQ_t))$$

Most empirical economic research in this area uses estimates of the output elasticity of infrastructure capital (Straub 2010) by applying regression techniques on multi periodic empirical data (Aschauer 1989). The elasticity states the responsiveness of the output on changes of the amount of infrastructure (Krugman 2009). For EAM we define this as follows, including that the output reacts on the quality improvements rather than on direct capital raise:

(3) $Output\ Elasticity\ of\ EAM = \frac{\%\ change\ in\ Y_t}{\%\ change\ in\ q_t}$

The obvious problem we face at this point is a lack of empirical data on EAM. While economists can use historical data of at least some decades, for EAM such data is not available yet. This leads to the impossibility at this point to apply regression techniques in order to calculate precise EAM output elasticity.

An economic effect to consider is induced by income taxes (Crafts 2009). If income is taxed to pay for public capital, these taxes reduce the after-tax rate of return of this capital (and thus of the infrastructure). This means that a decision to invest in public capital has two effects on growth: a positive one from the impact of public capital on the marginal productivity (productivity growth when adding one more unit of capital) of private capital, and a negative one from the impact of financing this public capital by taxing income. Such taxes are also relevant for profits that are generated by EAM. For that reason, we consider the topic of EAM costs to be even more important. Enterprise costs are usually modeled based on a cost function. Such functions include the amounts of labor costs (like wage rate) and capital costs (interests) (Seitz 1993). In an EAM model they further should include the costs of EAM.

Another variable that influences the productivity is the degree of development of a society, which is connected to *network effects* (Straub 2010). Such effects arise when the value to a consumer using a particular product increases with the amount of its other users (Brennan 2009). Infrastructure realizes lots of network effects. We can observe this effect in EAM theory, too. The more EAM is used in an enterprise, the more people put their information into EA models, and the more people find relevant information in these models, the more positive effects on the utility of EAM are created. However, if such efforts are undertaken while not keeping costs under control, positive monetary effects are reduced. We include this effect in our function q, by adding the relative amount (percentage) of EAM users (*EAMU*) in the enterprise into the function:

(4) $q_t(EA_t, EAMQ_t, EAMU_t)$

The result of most papers applying production functions is that infrastructure investments raise productivity (Aschauer 1989, Crafts 2009, Knaap, Ding and Hopkins 2001). However, the results are sometimes very high, e.g. the results of Aschauer (Aschauer 1989), implying that infrastructure investment pays off within one year (Gramlich 1994). More recent publications explain this result with the development of the highway network in the US at that time. The evidence seems to suggest that construction of the interstate highway network represented a step change in the quality of the transport system which had a dramatic effect on productivity but then ran into diminishing returns. Continuing investment on this scale would not have been appropriate (Crafts 2009). Therefore investments in maintenance can have positive influence rather than completely new investments (Straub 2010). Including also effects like income taxes lead to more realistic infrastructure returns (Crafts 2009).

It is questionable how appropriate production theory is for the domain of EAM. A major flaw is the lack of quality-related variables in productivity. Applying productivity measures to EAM might lead to the same discussion that already occurred about information systems, e.g. by Thatcher and Oliver (2001) and others.

Optimum Extent of Infrastructure

According to Straub (Straub 2010), The topic of investigating an infrastructure optimum has attracted very little attention so far in infrastructure economics. A major problem with optimality is to define the surrounding parameters that influence optimality (e.g. physical, geographical, and institutional). In general we identify two ends of a continuum: having only private investors that build roads or railways for themselves or having only a central institution that is authorized to build such networks. The decision is on how much of the infrastructure this institution should provide and how much private investors should built for themselves. The question arises, how much capital should be spent in order to support the public infrastructure and how much capital should stay with the single enterprise (Canning and Pedroni 2004). In the domain of EAM we see the same situation: is it worth to centralize certain planning, coordination and documentation tasks by a central actor (EAM) or is it only relevant for a certain project and should be kept there?

Canning and Pedroni (2004) apply the assumption that increasing infrastructure will tend to increase the level of output until a certain level is reached. Beyond that level, positive infrastructure investments will tend to reduce the level of output. This helps to identify where each society's infrastructure stock stands relative to the growth-maximizing level. However, this approach is only able to demonstrate the direction of the net effect of infrastructure on growth, not its magnitude.

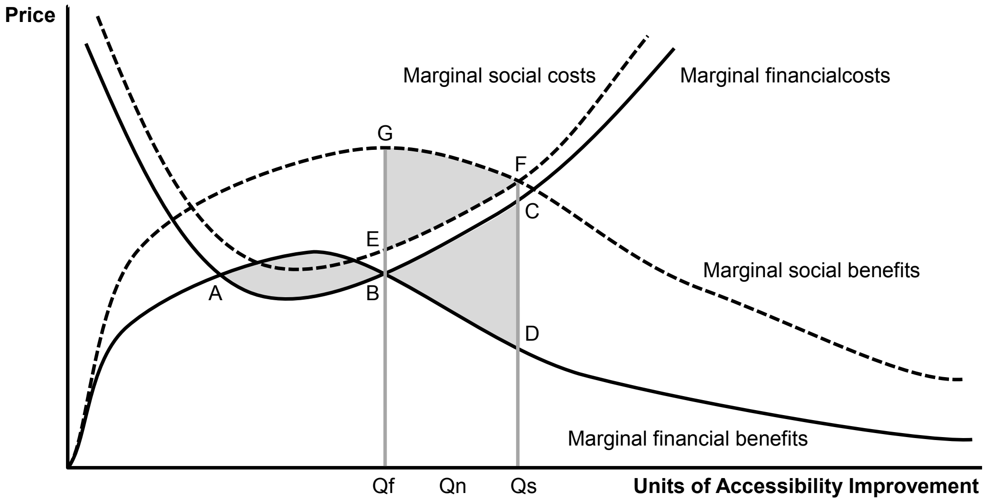
Another theoretical model is introduced by van der Krabben, Martens, De Graaff and Rietveld (2008). The analysis focuses not on production theory but on the impact of infrastructure on land and property values. The general assumption is that public investment in (railway) infrastructure results in approved accessibility which translates in higher property values. The authors distinguish between a social and a project optimum. The latter describes the optimum ratio between project related costs and the gain in financial benefits. The first refers to the optimum between social costs (e.g. negative environmental effects, negative economic effects in other areas) and benefits (e.g. traffic time savings, positive environmental effects).

The idea of having further social costs and benefits besides pure financial costs and benefits is very attractive for EAM. Social costs in EAM could cover e.g. de-motivation of employees since roles change or tasks are conducted by central departments. Benefits can be reduction of redundancies, providing better information basis for important transformations, finding a common language within the enterprise etc. Introducing additional social cost factors change the optimum calculations shown in figure 1.

Figure 1 illustrates the relation of marginal costs and benefit changes connected with units of accessibility improvement. The financial and the social optimum are usually not identical (*Qf* vs. *Qs*). Without budget restrictions it would be beneficial to invest until *Qs* (social optimum). The area AB is the margin that can be achieved when all financial costs are paid for. Such margin could be used in order to support the social goals, meaning to pay for the additional costs (BCD) that occur when moving towards the social optimum *Qs*. Since the regulatory body wants to achieve a social optimum, it should invest to achieve partial social margin (area EFG) or the social optimum. In figure 1 the costs that occur (BCD) in order to achieve the social optimum exceed the financial margin (AB). Not realizing the social optimum fosters the loss of the social benefits in area EFG. Projected on EAM, this model can be interpreted as follows: Pure optimization for project cost might not go far enough. Realized margins could be used in order to support social goals that go beyond the isolated project's perspective.

The formulation of a detailed optimization problem for EAM is a complex task and its influence factors need to be understood. Furthermore because of the lack of empirical data about EAM we would have major challenges to solve such an optimization problem in this paper. Additionally, if an optimal

Figure 1: Social and Financial Costs and Benefits (See van der Krabben, Martens, De Graaff and Rietveld 2008)



level of infrastructure would be determined, its realization by policy recommendations is difficult since regulatory bodies usually are not working under profit maximizing assumptions (Straub 2010) and their decisions are rather based on political calculus. In the domain of EAM culture is also considered to be important and the approach of principles is introduced in order to deal with this problem (Winter and Aier 2011). However, because of our economic scope in this paper, we will not further discuss theories from that field.

Management of Infrastructure

Infrastructure includes that a centralized management and provision up to a certain extend is necessary (Bird 1994). On the one hand, infrastructure management has to ensure to keep positive effects (scale-effects, connectability, etc.) alive. On the other hand, it is needed to avoid negative counterparts (monopolies, high prices, etc.). To achieve this goal, the regulatory body can take different roles:

First, it can serve as a *provider* of infrastructure, which is necessary according to the theory that no reasonable price can be achieved such as to yield a competitive return to the producer. The reason for this market failure is the non-excludability of infrastructure, implying that the market does not allow to properly allocate infrastructure resources to their most efficient use (Aschauer 1989). EAM is a technique that departments are not willing to accomplish by themselves or in many cases unwilling to initiate since benefits do not necessarily occur on their side but costs do. To our knowledge, there is no enterprise that deals with EAM as a profit center- it is usually treated as a cost center. These costs need to be allocated to the different departments, comparable to usage fees.

Second, since there seems to be an interest of private players to provide infrastructure(Straub 2010), the regulatory body in such cases does not provide the infrastructure itself. In this case, the role of the regulatory body focuses on *regulation* and ensuring standards that allow for interconnection between competing providers in order to keep positive network effects alive (Brennan 2009). For example, in the railway business, track ownership and maintenance got differentiated from train operations in order to foster competition as well as for economic rationalization (Profillidis 2001). For EAM this would mean to differentiate between people who maintain it and people who use it. Further this would imply that the first group is independent from the latter, meanwhile the latter acts as customer of the EAM provider.

Which advantages could such a governance model have? Market mechanisms would be established within the enterprise —from the perspective of the EAM user as much as from the perspective of the EAM provider. The provider would be forced to offer an efficient EAM product/service portfolio that provides the necessary information for the user at reasonable fees. The user on the other side has strong incentives to consider the EAM offer if it safes budget in projects. Establishing such mechanisms might help to find the optimal degree of EAM for the single enterprise. Furthermore the enforcement of standards is important in order keep EAM consistent when multiple concerns have to be considered and multiple people are involved in EAM development.

Apparently, we ask on which organizational level of an enterprise EA should be managed. Infrastructure decisions can be delegated to subunits, referred to as decentralization. Advantages are higher fulfillment of local needs and more reactive decision makers (Bird 1994). However, such advantages of decentralization can only appear if certain conditions are kept (Bird 1994): costs and benefits have to be transparent on the local level, costs of local decisions have to be fully paid by the local deciders and finally costs as well as benefits may not spill over to other actors. Delegation can still make sense if such conditions are not apparent, but incentives are properly set (and corruption and mismanagement are under control). The theory behind the delegation to lower levels are transaction costs (Bird 1994): Aggregating information on local conditions fosters less transaction costs than such an aggregation on an aggregate level. However, the desirable degree of decentralization may differ depending on the current stage (e.g. design, finance, construction, operation, maintenance, utilization) (Bird 1994). In order to coordinate the decentralized units, the regulatory mechanisms are needed, e.g. contracts that describe the tasks of the decentralized units. For EAM this guides to a governance model that, dependant on the scope of the EA, involves central and decentralized units.

For management of infrastructures there is evidence that even management on an aggregate (e.g. country) level might not be sufficient in some cases. According to (Hashimzade and Myles 2010), infrastructure investment has significant spillover effects across states, which influence the efficient level of infrastructure expenditure concerning the maximum rate of growth. Thus, the spillover between countries is a form of externality that results in inefficient investment in infrastructure if countries act independently. If there are positive infrastructural externalities between countries, then the provision of infrastructure will be inefficiently low when countries do not coordinate policies. Possible solutions are coordination authorities like the European Union. More concrete, risks are blackouts that spread over to other countries like in North America, where much of the electricity grid is common to the US and Canada (Brennan 2009). If we consider these aspects for EAM, we have to think about the evidence of collaborative EAM. This implies the inclusion of external partners into EAM (an example is the TOGAF framework, jointly developed by an industrial consortium (The Open Group 2009)).

Towards a Research Agenda

Our goal stated in the introduction was to understand the design of cost effective EAM. The discussion above shows that even in economics with its established explanatory theories, cause-effect statements cannot be easily transformed into means-end relations (design theories) that practitioners can use to develop problem solutions. For our research this implies that it is not sufficient to only generate hypothesizes based on economic explanatory theory and validate them. Instead, we need to develop and evaluate design theories in order to allow for the construction of reasonable solutions in future research. However, the economic perspective helps us to identify areas to be considered more in depth in future research. In detail we propose to develop design theories by considering the following aspects and areas of research.

Focus of the Analysis

We notice that dealing with infrastructure on a theoretical level is a very abstract topic. Many of the theories we briefly discussed above can be also applied to information systems fields other than EAM (e.g. information logistics management, enterprise resource management). We argue that these systems also can be considered as infrastructure. We therefore summarize them with the term information system infrastructure (ISI) and propose the following three levels to analyze infrastructures:

1. *Generic Infrastructure*: This level covers components and relations that all infrastructures (including ISI and traditional infrastructures) have in common (e.g. interconnected subsystems).

2. *Generic Information Systems Infrastructure:* This level covers components and relations that all ISIs have in common. Therefore, aspects that are only relevant for traditional infrastructures should not be covered on this level.

3. *Specific Information Systems Infrastructure*: This level is supposed to cover components and relations of specific sub-types of ISIs – like EAM. For example, influence factors that only appear for the analysis of EAM are covered on this level.

The body of research in the first level is very large and not primarily addressed by information systems research (ISR). Lots of research in ISR however is conducted on the third level. Researchers interested in different domains of ISR dealt independently with relevant factors, e.g. cost-benefit considerations about ERP (Hitt, Wu and Zhou 2002), about decision support (Pieptea and Anderson 1987) and many others. Therefore, we consider the second level of abstraction to be most interesting for future research. The goal is the development of design theories that are valuable for the design of different systems depending on their characteristics rather than purpose.

Influence Factors on Productivity

We noticed that a discussion about productivity on an abstract level will not lead to meaningful results, therefore underlying factors need in-depth analysis. The challenge is to gather data that allows for such analyses, approaches that need rather small data foundations, like simulation (Badiru and Sieger 1998), might be applied. Simulation as such is an alternative to other mathematical techniques because rather than solving models in general, it creates highly specific simulation runs that need to be consolidated later on in order to derive general evaluations (Orcutt 1960). Simulation already has been applied to develop theories for situations were empirical data is rare, like pricing strategies in software markets (Buxmann 2001).

Like discussed above, consideration of quality indicators is necessary. Furthermore, aspects should be discussed that focus on different actors in an organization. If nobody uses the infrastructure, investments will not enable productivity gains. Therefore the large body of technology acceptance literature (e.g. Venkatesh, Morris, Davis and Davis 2003) should be analyzed considering the specific characteristics of infrastructure - like the ones identified in conjunction with answering the first research question. Also addressing the behavior of actors, the perspective of institutional theory (North 1990, Scott 2001, Selznick 1948) and, related to that, aspects of organizational culture (Schein 1997) are of importance. A specific question is which EAM designs provoke the adoption and diffusion of EAM in organizations and which design factors rather foster avoidance defiance or even manipulation strategies towards EAM initiatives (Oliver 1991).

Internal Markets and Regulation

We found theory and models in economic research that explain why infrastructure is necessary for societies. Especially the presumed market failures, and necessary regulation seem to be worth to be analyzed more in depth. Considering the literature analyzed so far, different circumstances foster different kinds of market failure and thus require different extents and realizations of regulation. In this paper we analyzed economic theory rather broad than deep. The aspect of regulation from our point of view is worth to be analyzed more in depth in order to understand, how infrastructure should be regulated in certain scenarios.

For such an analysis we further propose not to restrict the search to economic theory. Many relevant findings might also be drawn from political and social sciences' research.

The discussion of market failure focuses on the question of why an enterprise needs to centrally invest in EAM and which unfavorable effects occur without this investment. Economic theory on infrastructure provides a very appealing view on this discussion because it clarifies that traditional business cases which can be reliably calculated for more focused information systems like customer relationship management systems production planning systems, for example, are not appropriate for ISIs.

Stakeholder Groups and their Interests

The work by van der Krabben, Martens, De Graaff and Rietveld (2008) shows that infrastructure is driven by different stakeholder interests that need to be aligned or jointly optimized. In order to work on this aspect, we especially consider explorative interviews or focus groups in enterprises suitable. For this aspect we also consider qualitative research to be interesting that is not limited to experts in the field of ISI but also experts that deal with public infrastructure. Such a perspective can lead to new insights for the management of ISI. As with every subsidization-like investments the balance of internal efficiency (achieving a desired result with minimal costs) and external efficiency (serving every socially legitimate demand for infrastructure services) is crucial.

Contribution and Limitations

In this paper we discussed the analogy between EAM and the management of infrastructures in general. We found that there are many similarities not only with EAM, but even with other sub-types of information system infrastructures. The most important characteristics to consider an information system as ISI are control (in terms of regulation), investment motivation (failure of private markets) and the distinct moments and areas of benefit realization. Findings from the discussion of economic theories about infrastructure are that these cannot be applied in a one-to-one manner on EAM, but provide new starting points for the development of EAM related design theory. Such starting points especially are the extended focus of analysis, influence factors on productivity, internal markets and regulation as much as stakeholder groups and their interests. We discussed details about these aspects in the stated research agenda that provides next steps in order to derive the needed design theories.

By the concept of the paper some limitations need to be considered. Our discussion does not cover all existing economic theories. However, this was not the purpose of the paper since we decided to use the discussions of economists about infrastructure as our starting point. Further we could not discuss theories in depth in this paper, which we also did not consider to be the focus of the paper. Therefore we do not provide a completed analytical framework that has been evaluated empirically but a research agenda based on our initial idea of the infrastructure/EAM analogy. We are aware that the paper presented is the first step for further research that covers these critics and provide evaluated research.

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