On the Economic Nature of Medical Information: Implications for the Development of Information Infrastructures in the Healthcare Sector

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Abstract

IT adoption in the healthcare sector still lags behind expectations. The literature has extensively studied IT adoption in the healthcare sector as a problem of information infrastructure development. We extend that literature by adding a supply chain perspective which treats information infrastructures as assemblies of information components. This allows us to apply the theory of collective action to these individual components rather than to the information infrastructure as a whole, as is characteristic of the information infrastructure literature. We find that some information components have the character of common resource pool goods, which require specialized and local institutional arrangements to overcome the implied free-rider problem. This sheds a new light on the current problems of slow IT adoption in the healthcare sector.

Keywords: Collective action theory, Ostroms' classification of types of goods, clinical medication review, information infrastructure, healthcare industry

1. Introduction

Digital disruption has become a phenomenon of the 21st century that is transformational in most traditional industrial contexts (Ford et al., 2017) and affects all levels of business and society (Schallmo & Williams, 2018). Information technologies (IT) have been adopted in the healthcare sector since the mid-20th century (Ford et al., 2017). This has led to improved medical research and care delivery (Kraus et al., 2021). The opening of the Internet for commercial purposes in the mid-1990s has further impacted the way in which health service providers and patients communicate (Arni & Laddha, 2017; Suggs, 2006). However, adoption of IT and Internet by healthcare organizations has only incrementally changed the healthcare industry over the last 20 years (Tuzii, 2017). Moreover, in spite of strong motives for speeding up IT adoption in the healthcare sector, various large national e-health programs conducted over the past twenty years are now considered to have largely failed (Constantinides & Barrett, 2015; Currie, 2012; Omar et al., 2017).

A particular challenge consists in the establishment of nation-wide electronic patient record (EPR) systems (Hanseth et al. 2006; Aanestad & Jensen, 2011; Major Projects Authority, 2011; Currie, 2012; Constantinides & Barrett, 2015). While much research has addressed the complexity implied in developing national information infrastructures resulting from the large number and heterogeneity of their human and non-human components (e.g., Star & Ruhleder, 1996; Hanseth & Lyytinen, 2010), the issue of regional scale as such, as implicated in efforts to errect nation-wide EPR systems, has received much less attention. In particular, information infrastructure development has been shown to involve intricate problems of collective action (Markus et al., 2006; Constantinides & Barrett, 2015), which suggests that the difficulties associated with information infrastructure development also increase with regional scale. While local solutions to addressing problems of collective action may be variously available, availability of appropriate governance structures on a national scale is much less likely (Ostrom, 1990).

Collective action theory has been employed to analyze the chicken-and-egg problem characteristic of the early stages of information infrastructure development (Markus et al., 2006), complementing architectural approaches towards addressing this problem (Hanseth & Lyytinen, 2010; Aanestad & Jensen, 2011). However, problems of collective action may also be implicated in the continuous operation of information infrastructures.

Information infrastructure development has been extensively studied as a problem of combining or assembling heterogeneous human and non-human components (Fürstenau et al., 2019; Hanseth & Rodon, 2021). In this paper, we extend this approach

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by viewing such assembly processes not as a one-time construction effort, but as a continuous production process. The literature tends to view information infrastructure as a transportation system for *moving* information, implying that information itself is not seen as a component of that structure. However, information infrastructure may also be seen as a system *producing* information. In that case, the assembly of an information infrastructure comes to resemble a traditional supply chain which converts information inputs into information outputs. When applied to information infrastructure, the question of how to provide the required information input becomes prominent since the provisioning of such information cannot simply be mandated, as is the case for enterprise-wide information systems, but depends on the willingness of various actors not aided by a unified hierarchical governance structure. An important question then concerns the economic nature of such information. In traditional supply chains, intermediate goods typically have the character of private goods and are bought and sold on markets accordingly. But what is the economic nature of intermediate information goods as essential components of health information infrastructures?

If such information has the character of private goods, health information infrastructures, understood as production systems, could be operated and maintained like traditional supply chains. If, by contrast, it has the character of public goods, health information infrastructures should be operated and maintained by the state and its agencies. But if it has the character of a collective good, other, more elaborate forms of governance are necessary to overcome the implied collective action problems. In that case, significant barriers to extending the regional scale of health information infrastructures are to be expected since appropriate governance structures may not easily be extended too.

In this paper, we will apply the classification scheme of good types developed by Elinor and Vincent Ostrom to answer our research question: What is the economic nature of medical information making up a health information infrastructure? We will then turn to the particular case of medication information to argue that the usefulness of such information, contrary to the standard assumption, wears off with use while most potential users cannot be excluded from its use, which qualifies medication information as an instance of so-called common resource pool goods. In the subsequent section, we will then discuss the theoretical and practical implications of that analysis for the development of health information infrastructures and address the limitations of our analysis. The concluding section summarizes the contributions of our paper.

2. Ostroms' classification of good types

The theory of collective action as developed by Elinor and Vincent Ostrom (Rayamajhee & Paniagua, 2021) offers valuable insights with regard to the problem of information sharing in supply chains. The study of IS phenomena at the industry level has previously been aided by a collective action approach, specifically with regard to the development of industry-wide inter-organizational information systems (Markus et al., 2006; Constantinides & Barrett, 2015). Markus et al. (2006) understand an industry-wide inter-organizational information system as a collective good and hence focus on problems of free-riding in their analysis. Constantinides and Barrett (2015) reconstruct a failed initiative to set up a national electronic patient record (EPR) system in Crete as a dialectic of ideologies concerning the question of whether such a system should be viewed as a public or a private good and recommend a polycentric governance structure as a principal solution to such problems since this would 'decouple' ideological domains and hence facilitate their coexistence. The framework developed by Elinor and Vincent Ostrom (referred to as 'the Ostroms' in the following) offers a broader and more comprehensive approach by distinguishing four kinds of goods as illustrated in Figure 1. These goods are distinct in two dimensions: subtractability and excludability. The first (subtractability) refers to the degree that consumption of the good reduces ("subtracts from") its value for others. In the extreme case, consumption is non-rivalrous. Excludability refers to the degree to which potential consumers can be denied consumption (Rayamajhee & Paniagua, 2021).

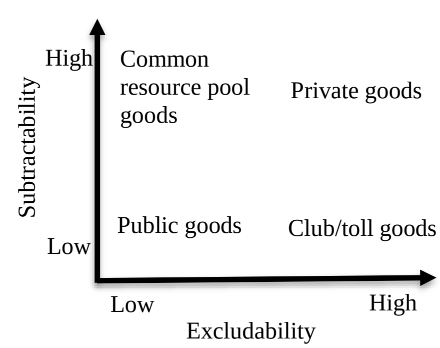

Figure 1. Distinction between four kinds of goods as classified by the Ostroms
(Source: Rayamajhee and Paniagua (2021))

The direct pay-off of this approach is that it broadens the debate as to whether certain economic phenomena should be treated as public or private goods since it offers two further possibilities. Moreover, the Ostroms have argued that the analysis of common resource pool goods, characterized by a high degree of subtractability and a low degree of excludability, which are prone to the free-rider problem, should not be restricted to the standard solutions to the free-rider problem as offered by the literature (Olson, 1965). Instead, they have empirically identified numerous, locally adapted, and innovative solutions to the free-rider problem and have synthesized these through the analytical concepts of co-production, institutional matching, and polycentric governance (Rayamajhee & Paniagua, 2021). Finally, the Ostroms have shown that the criteria of subtractability and excludability should not be taken as given but as contingent on changeable technical and institutional conditions (ibid.).

This framework has been previously applied to information goods. Hess and Ostrom (2003) characterize scientific information as a common resource pool good and call for new forms of collective action to keep scientific information in the public domain. However, these authors also characterize scientific information as non-subtractive, except for special cases such as when, in a public library, the physical copy of an academic journal is temporarily unavailable because it has been borrowed by another user, thus contradicting its classification as a common resource pool good. Vassilakopoulou et al. (2016), in their analysis of various initiatives to make information about certain human genes publically available, likewise characterize such information as a common resource pool good. Based on their case analysis, these authors argue that the properties of excludability and subtractability are not externally given but are shaped by the conflict-laden negotiation processes of various key stakeholders. However, Vassilakopoulou et al. also embrace the view that information is generally characterized by non-subtractability, while arguing that, in their case, the decision by one large player to withhold important information items from the public domain shaped the property of subtractability of that information. However, this argument confuses the two properties of excludability and subtractability. Withholding information is evidence of its excludability, not of its subtractability. Hence, in both these studies the classification of information as a common resource pool is only claimed but not demonstrated.

3. The example of clinical medication reviews

In this section, we use the example of clinical medication reviews to illustrate how application of the Ostroms' framework can help in the analysis of information infrastructure development processes.

3.1. The information supply chain of clinical medication reviews

A medication review is a systematic assessment of a patient's medication with the aim of optimizing the use of medicines and minimizing medication-related problems (Clinical Excellence Commission, 2019). The key outcomes of a medication review include the identification of actual and potential drug-related problems and recommendations to optimize medicine use. Identified problems and recommendations should be documented and actions prioritized according to their risk and urgency (SHPA, 2016).

Depending on the purpose of the review and the particular needs of the patient, three types of medication reviews are distinguished: medication order review, medication adherence review, and clinical medication review (Clyne et al., 2008). A medication order review is the simplest review type and a clinical medication review the most comprehensive. In addition, a clinical medication review includes the elements of a medication order review as well as a medication adherence review.

The purpose of a clinical medication review is to address issues relating to the patient's use of medicines in the context of their clinical condition/s, with the aim of reaching an agreement about the treatment with medicines, optimizing the effect of medicines, and minimizing drug-related problems (Clinical Excellence Commission, 2019; ACSQHC, 2017; Clyne et al., 2008). A clinical medication review involves a structured, comprehensive review of the patient's medication. It considers the management of the conditions being treated and the appropriateness and continuing need of each drug, as well as potential gaps in therapy. Partnering with the patient is essential when undertaking a clinical medication review. A clinical medication review requires gathering patient-specific information about their clinical condition and medicine use and then evaluating the information to guide treatment. Table 1 shows the patient-specific information components of a clinical medication review, including possible providers for each component.

Table 1. Information components of clinical medication reviews and possible providers

Information component	*Information provider*
Allergies and adverse drug reactions	Patient, Relatives, Physician, Pharmacist
What medicines the patient currently uses and why	Patient, Relatives, Physician, Pharmacist
How the patient takes their medicines, including dose and frequency	Patient, Relatives, Physician, Pharmacist
Patient's medication adherence	Patient, Relatives, Nurse
How the patient physically manages their medicines, e.g., storage, use of dose administration aids	Patient, Relatives, Nurse
Whether the patient experiences difficulties using their medicines, e.g. opening bottles, using inhalation devices	Patient, Relatives, Nurse
The patient's satisfaction with the outcomes of their drug therapy, including the patient's beliefs about their medicines	Patient
Past prescription records	Physician, Pharmacist

As shown in Table 1, most information required for a clinical medication review can be obtained from the patient. However, patients are notoriously unreliable in providing such information (Kohn et al., 2000). Moreover, assembling such information based on patient information is a labor- and time-intensive process which practically and economically limits the provisioning of clinical medication reviews. To overcome this limitation, medication plans are increasingly being used to facilitate medication reviews. For example, since 2017 all patients in Germany who regularly take three or more prescription drugs can request a medication plan from their family doctors. Introduction of this law is considered an important step towards improving the medication therapy safety of an aging population (Krüger-Brand, 2015). In a further step towards this goal, new legislation has been introduced in 2021 which entitles patients who regularly take more than five prescription drugs to have a clinical medication review performed for them by a community pharmacist once per year. While it will take a while before these legal measures become part of actual practices, we can envision an information supply chain for clinical medication reviews similar to that depicted in Figure 2. Medication plans thus become an intermediate information good for the production of clinical medication reviews.

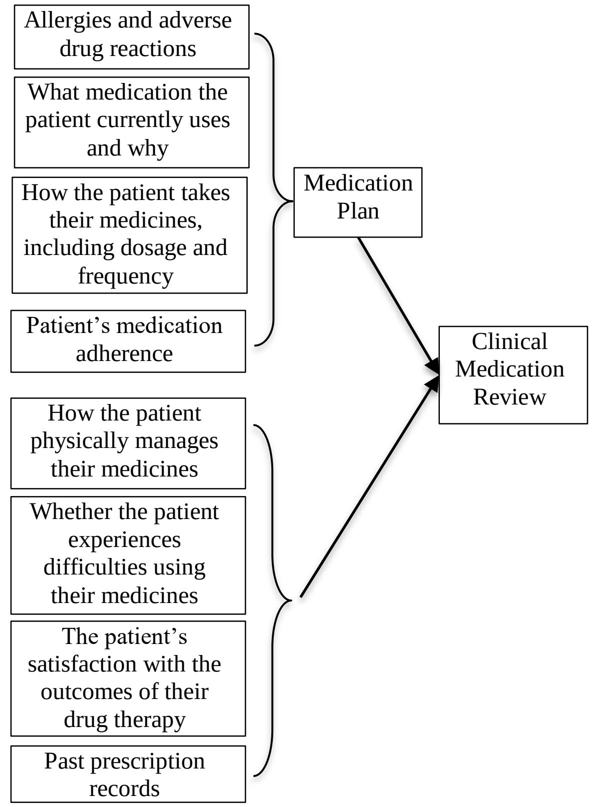

Figure 2. Stylized information supply chain of medication reviews

3.2. The medication plan as a common resource pool good

We can now draw on the Ostroms' classification scheme to inquire about the economic nature of medication plans. Intuitively, it seems plausible to classify medication plans as club goods. For example, information about allergies and adverse drug reactions concerns a particular patient and hence his or her privacy. Therefore, any use of this information by others must be authorized by the patient, which seems to imply a high degree of excludability. In addition, it appears that the value of such information is not reduced by its use, which implies a low degree of subtractability. Accordingly, such information should be seen as a club good and the primary solution to providing it would be to let patients control who has access to it.

However, this analysis is based on a static understanding of patient-related medication information. Information is seen as an entity, not as a process. Yet, medication-related information is in a process of continuous change. Patients may decide to change dosages or to take non-prescription drugs, pharmacists may substitute drugs by generics, and medical specialists may prescribe further drugs. Hence, information about medication is better seen as a process of continuous updating than as a static entity that is provided once and then free to use. In fact, simply using such information without updating it subtracts from its value. For example, a specialist who checks the medication plan of a patient stored in an electronic record in order to decide which drug to prescribe but then does not update the medication plan *reduces* the value of the information provided by the medication plan since the information contained in it no longer represents actual intended medication use. Hence, the various actors involved in the medication process of a particular patient, including the patient himself or herself, must continuously contribute to keeping that information up to date. If they fail to do so, the information is quickly outdated. Such information is similar to a shared road which must be continuously maintained in order to function properly. Just using it will quickly lead to its deterioration. In short, information which must be continuously updated in order to remain valuable is characterized by a *high* degree of subtractability. Simply using it without updating it will reduce its value for the next user.

Similarly, the common assumption that such information is characterized by a high degree of excludability also does not stand up to scrutiny. While, formally, patients may be in control of who has access to their medication-related information, in practice they are forced to grant access to any healthcare provider even if that provider does not contribute to its maintenance. Providers will simply refuse to treat a patient if they are not granted such access. Hence, such information is, in fact, characterized by a low degree of excludability. In consequence, the provisioning of such information depends on overcoming the free-rider problem characteristic of common resource pool goods.

This characterization of medication-related information becomes even clearer when considering the case of past prescription records. Such information is, indeed, static. It does not change any more since it records a medication-related decision in the past. By contrast, current medication information needs to be continually updated to reflect continuously changing medication intentions, which look to the future. Moreover, access to past medication records may be effectively denied by the patient, mostly because it is only of secondary importance for a medication review. Thus, past prescription records do, indeed, conform to the notion of a club good, but they may constitute the least important information component of a medication review. This is also consistent with Fulk et al.'s analysis of properties of information goods, namely that information is "reproduced for the collective rather than transferred to it" (Fulk et al., 2004, p. 570).

4. Discussion

In this section, we discuss the theoretical and practical implications of our analysis and address its limitations.

4.1. Theoretical implications

We see two implications of our analysis for the theory of information infrastructure development, namely with regard to the economic nature of information on the one hand and to the assemblage approach to information infrastructure development on the other hand.

(1) As already noted, information is generally seen as non-subtractive, even in cases when it is characterized as a common resource pool good, as shown in Section 2. In addition, scholars have claimed that information may even display the opposite effect, the so-called data network effect (Gregory et al., 2021). According to this hypothesis, use of information may actually increase its usefulness for other users instead of diminishing it, because every use generates new data – usage traces – which can be combined with the original information to generate new use value. So how can we account for the possibility of subtractability of information in a more general manner and thus distinguish different classes of information characterized by data network effects ('additivity'), non-subtractability, and subtractability respectively?

Responding to a critical appraisal of their approach by Clough and Wu (2022), Gregory et al. (2022) have clarified the conditions under which they believe that data network effects are possible, namely when analysis of data of a particular user benefits other users as well and when such benefits are realized so quickly that they become manifest for all current users rather than only for future users. This, Gregory et al. claim, is generally only possible through application of AI techniques (ibid.). This scenario thus imagines a form of active use of information which channels the results of such efforts back to other users. The example of medication data can be seen as representing the opposite of that scenario, where users do not channel the results of their use back to other users. But this only accounts for a failure to add use value to information through its usage, not for the subtractability of information.

The fact that even scholars who intend to demonstrate that, for some cases, information may have the character of common resource pool goods tend to emphasize the non-subtractability of information calls for a more fundamental analysis of the criterion which discriminates cases of non-subtractability and subtractability, if the latter exist at all. Returning to our example of medication data, one may argue that the real problem is not information subtractability, but failure of participants in a medication therapy to update medication data. This is the route taken by Vassilikapoulou et al. (2016) in their study of collaborative analysis of genetic data. In discussing the possibility of information subtractability, they refer to a decision by a large player to withhold results of analyses of genetic data from the public domain. But in that case, the use value of the extant data pool is not diminished, but simply not added to. The results of genetic data already contained in the common pool do not lose anything of their value for others.

The criterion that distinguishes between the two cases, genetic data and medication data, is that genetic data refer to an object which does not include the behavior of the data analyst. In other words, the data do not change through the behavior of the data user. This is different for the case of medication data. These data are not just about the patient, as suggested by the phrase ‘patient data’, but also about the prescribing behavior of physicians and the dispensing behavior of pharmacists as well the drug taking behavior of patients. We therefore suggest that subtractability of information pertains when the object represented by the data includes the behavior of their users.

Based on this criterion, other such instances of that situation can be identified, e.g. price generation on stock markets. Users of such data, dealers and brokers on a stock exchange, change prices – and hence price data – because their behavior is part of the process through which prices are generated (Mulherin et al., 1991). Hence, all stock exchanges have elaborate rules that regulate how information about each participant’s behavior is fed back into common pool resource that the published price represents (ibid., Reimers, 1996). Ultimately, we propose, the criterion refers to the possibility of separating the observed object from the observer; whenever the observer is part of the observed object, information representing the object displays the property of subtractability.

(2) Information as such is not often discussed as an essential component of information infrastructure since, as argued above, information infrastructure is typically seen as a transportation system that moves information, not as a system that produces information. A notable exception concerns Bowker and Star’s seminal analysis of the evolution of various classification systems in the healthcare sector (Bowker & Star, 1999). However, their analysis also approaches information infrastructure from an architectural perspective, as consisting of a hierarchically ordered system of information classes which then provide the containers for actual information produced in healthcare practices.

Our supply chain-inspired approach to information infrastructure suggests an interesting extension to the assemblage theory of information infrastructure. While the assemblage approach refers to information infrastructure as a construction consisting of components such as hardware, software, interface standards, use knowledge, and organizational routines (Fürstenau et al., 2019; Hanseth and Rodon, 2021), from a supply chain perspective the flow of information is viewed as constituting an information infrastructure. An information infrastructure then appears as ‘assembled on the fly’, i.e., as continuously re-enacted or performed rather than once built and then occasionally repaired and extended. The question of how to assemble an information infrastructure then turns to how to combine the various information components into a usable service or product. For this to be possible, the various information components need to be combinable, i.e., interoperable, and one way to achieve this is through standardized interfaces. Bowker and Star’s (1999) analysis of the ICD, the International Classification of Diseases, approaches this question from an architectural point of view, as already observed. However, one may also view the ICD as the outcome of uncounted performances of the various practices of physicians and other healthcare providers, i.e., as emergent. We therefore suggest that such an evolutionary approach to information infrastructure may be usefully explored as it may complement the design-oriented architectural approaches to information infrastructure development. For didactical illustration, information infrastructure development may be compared to the way that the interaction between rocky material and water flows shapes mountains and valleys, which represent an information infrastructure in this metaphor. From one perspective, a mountain valley may be seen as directing the flow of the river that runs through it. But it is equally possible to view the shape of the valley as resulting from the flow of the river.

4.2. Practical implications

With few exceptions (e.g., Bernard & Exworthy, 2020), current approaches to building information infrastructures in the healthcare sector are based on the implicit assumption that most relevant information has the character of club goods characterized by a high degree of excludability and a low degree of subtractability. Hence, patients are placed in the position of gate keepers who decide who has access to 'their' information and thus who is allowed into the club. For example, Germany's current large scale effort to establish nationally shared electronic patient records follows this logic.

However, such approaches treat the information components of healthcare services as static entities that, once provided, can be freely used without subtracting from their value. Moreover, being able to grant or deny access to such information is seen as a sufficient incentive to entice healthcare providers to supply such information.

However, from a supply chain perspective, these information components should be viewed as a process of continuous maintenance. Healthcare providers need to continually update and purge electronic records in order to keep them useful, because, as shown above, using such data implies changing them. Otherwise, their usefulness quickly deteriorates. In contrast to traditional supply chains concerned with the provisioning of physical goods, information components of healthcare services do not have the character of private goods that can be bought and sold on markets. Instead, they have the character of a common resource pool good characterized by the possibility of free-riding. Overcoming this problem requires complex institutional arrangements (governance structures) which must be tailored to the specific situation at hand, as argued by Ostrom (1990, 2003). The incentive of granting or denying access to medication-related information is ineffective in this regard since healthcare providers will simply refuse to treat patients if they do not grant such access.

Based on our own initial research findings, it seems that such arrangements are possible at the local level. For example, shared electronic records in the U.K. are maintained at the level of so-called trusts, local and semi-self-governing healthcare provisioning networks coordinated by large hospitals. In Finland, we have found that shared electronic patient records can be effectively maintained at the district level. Accordingly, both countries have backed away from large-scale efforts to establish shared electronic records at that national level. We hypothesize that this can be explained by the need to find locally adapted and effective solutions to the free-riding problem associated with the character of patient-related information as a common resource pool good. By contrast, approaches based on the implicit assumption that such information has the character of club goods may be ineffective since they ignore the processual character of such information. The processual character of this information, in turn, is highlighted when a supply chain perspective is adopted.

4.3. Limitations

This is a conceptual paper and its conclusions are supported empirically only through the experience the authors have gained through active involvement in the healthcare industry in China and Germany as well as the anecdotal evidence cited above. Also, the published evidence that we quoted earlier in support of our hypothesis, that efforts to establish nation-wide electronic patient records have largely failed, is not detailed enough to support our claim that this is due to problems of collective action associated with the common resource pool character of medical information. Finally, our example of medication data may turn out to have been picked conveniently to support our hypothesis while the majority of medical data do not share this characteristic. For example, X-ray images and results of laboratory analyses of blood probes would not seem to suffer from the same problem as use of such data does not imply changing them. Hence, it is possible that the majority of data intended to be stored in national EPR systems do not suffer from the problems we have highlighted in our analysis. Systematic, internationally comparative studies of national EPR projects and their long-term development are necessary to support or disprove our analysis.

5. Conclusion

In this paper we have made three contributions. First, we have clarified under which conditions information may display the property of subtractability. While information, including in the health domain, has previously been characterized as a common resource pool good, which implies that it has both a high degree of subtractability and a low degree of excludability, the mechanism accounting for its subtractability has not yet been clarified. We found that this mechanism consists in the inclusion of the behavior of the information user in the object represented by the information. This allows us to discriminate cases of subtractability and non-subtractability.

Second, based on our theoretical analysis of information subtractability, we have proposed a novel explanation which could account for the difficulties to establish nation-wide EPR systems. In particular, if a significant portion of data included in an EPR system displays the characteristic of common resource pool goods, then locally adapted governance structures are called for to overcome the implied free-rider problem. Consequently, nation-wide EPR systems will suffer from free-rider problems and thus fail to deliver on their promised benefits.

Third, our analysis offers a process perspective on information infrastructure development which views information infrastructure as the emergent result of an ongoing process of information production through uncounted re-enactments of various practices. This complements architectural approaches towards information infrastructure development and extends the assemblage approach by viewing information infrastructure as an information supply chain which is assembled 'on the fly'.

Our analysis is conceptual and based on first-hand experiences of the authors as well anecdotal evidence. To corroborate or reject our analysis, systematic, internationally comparative studies of EPR projects and their ongoing development are called for.

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