Research Article

Sociotechnical Dynamics in IS Development in Organizations: The Case of a Resource-Constrained and Competitive Context

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Abstract

The literature on IS development in developing countries mainly deals with the interplay between ISs, often brought from abroad, and use contexts. This research, however, considers a locally developed IS, primarily examining the interests and strategies of human and nonhuman actors embedded in an IS and the wider sociotechnical network, as well as their respective implications for implementation contexts. Focusing on the public health sector of Ethiopia, the study examines the design dynamics of an IS over time and space vis-à-vis the use context by adopting an interpretative, qualitative case study approach. The findings reveal that the resulting IS and sociotechnical network embed mainly the interests, strategies, and ideologies of the dominant actor (the actor that defines both problems and solutions), regardless of realities in implementation contexts, and at the expense of organizational performance and effectiveness. The research reveals that IS development and implementation is a complex sociotechnical process where data quality, performance, and sustainability are negotiated orders. The study also shows the relevance of actor-network theory for explicating the development of ISs in organizations and identifying both human and nonhuman actors and their associations.

1. Introduction

The design and use choices for an IS are influenced by an individual's knowledge, expectations, and assumptions concerning the purpose, context, importance, and role of a technology in a given context (Bijker, 1995; Markus, 1983; Orlikowski, 1992; Pinch & Bijker, 1984). As social artifacts, the material forms and functions of technologies embody their sponsors' and developers' objectives, values, interests, and knowledge about that technology (Orlikowski & Gash, 1994). For example, the choice made by sponsors and developers to either centralize or decentralize an IS determines the process of work, division of labor, autonomy of employees, and decentralization or centralization of units and decisions. Besides human agency, technology could also influence the path of its development and use (Barley, 1986). Thus, technological artifacts are not exclusively the result of pure engineering and design processes; they are value-laden and embedded with the interests of actors[1] (Bakardjieva &

1. In keeping with actor-network theory, the terms "actor" and "actant" are used interchangeably in this article.

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Feenberg, 2002; Feenberg, 2000; Orlikowski & Gash, 1992).

The study of technologies in organizations should therefore entail considering the roles of both technologies and humans (Markus & Robey, 1988; Orlikowski, 1996; Orlikowski & Barley, 2001). Ignoring the role of humans in shaping technology or denying the material affordances and constraints of technologies is an inadequate approach for studying the development and use of technologies in organizations (Orlikowski, 2000). The interplay between organizations and ISs can best be explained at a lower level of abstraction (Hanseth & Monteiro, 1998) by giving due attention to the IT artifact (Hanseth, Aanestad, & Berg, 2004; Monteiro & Hanseth, 1995; Orlikowski & Iacono, 2001). The implementation literature focuses mainly on the interaction between specific organizational practices and IS presumptions (Pollock, Williams, & D'Adderio, 2007). Such has been the case in IS development projects in developing countries: Software was often brought from abroad, and effort was spent adapting it to the use context or vice versa. To complicate matters, further effort was usually expended simultaneously on trying to develop indigenous technological capacity (Braa, Monteiro, & Reinert, 1995; Heeks, 2002; Heeks & Stanforth, 2007; Nhampossa, 2005; Odedra, 1992).

Unlike previous studies, this research focuses on a locally developed IS that originated in a highly contested context. The article uncovers actors' interests that shaped the material forms and functions of the IS. It also explores the dynamics of role allocation and the implications they have for implementation goals, sustainability, and organizational change. The research was guided by the following questions: Which interests of actors were embedded into an IS? What are the implications and effects of embedded interests and anticipated patterns of use in adopting organizations and vice versa? How did the actors' interests influence role delegation? What part does role allocation play in sustaining sociotechnical networks? Examining these issues would improve our understanding of IS design and enactment processes, their impact on adopting organizations, their implementation processes, and the sustainability of sociotechnical networks.

The empirical material for this research was collected in the public health sector of Ethiopia, where a number of donors wished to introduce a computer-based antiretroviral therapy[2] (ART) IS—hereafter, ARTIS—in ART clinics. Some of the donors had agreements with the federal government of Ethiopia to technically support ART, while others, like HISP,[3] did not. HISP had developed and introduced an open-source ARTIS in the capital city, Addis Ababa, in 2006, and had subsequently tried to implement it in other parts of the country. This attempt turned the IS development environment into one of competition and politics, rather than one of collaboration, which influenced the choice of development technologies, methodology, ideology, features, and functions. Ultimately, this occurrence specified the current and future patterns of use, the project trajectories, and the natures of adopting organizations. The article shows the sociotechnical dynamism of IS development in a resource-constrained and competitive context.

The rest of the paper is organized as follows: The next section discusses the conceptual foundations used in the study, drawing from the literature on IS design and translation. Then, the research context and key research methods are discussed, and a detailed description of an empirical case study on the development of an IS in the public health sector of Ethiopia is provided. This is followed by an in-depth analysis of the case study and concluding remarks with some implications for practice and theory.

2. IS Design and Translations

Although ICT has been accepted as relevant to developing countries, its application to development goals has not been always successful (Walsham, Robey, & Sahay, 2007). IS implementation in developing countries has been challenging, and the failure rate has been high (Avgerou, 2008; Heeks, 2002, 2006; Walsham et al., 2007). Some of the most commonly cited problems include country context gaps and gaps between IS designs and realities

2. ART is a lifelong treatment for AIDS patients.

3. HISP stands for Health Information System Program. It is a network of health institutions and academics in developed and developing countries. HISP works toward strengthening HIS in developing countries. See Braa, Monteiro, and Sahay (2004) and http://www.hisp.org for further information on HISP.

in implementation contexts (design-reality gap), as well as the general lack of resources and indigenous techno-scientific capacity. Context disparity could be eliminated by developing ISs locally, but understanding the problem domain and the influences of the socio-technical context remain two difficult tasks. These obstacles are the focus of this research.

During IS development, designers transform themselves into sociologists, moralists, or political scientists at different moments (Callon, 1991). Given the underlying understanding that increased knowledge of users and the environment leads to better design, they work closely with users (Pollock et al., 2007). They make both hypotheses about the entities that make up the world into which the IS is to be inserted, and concrete judgments about anticipations and restrictions of future patterns of use (Akrich, 1992; Monteiro, 2000). Akrich explains:

> Designers . . . define actors with specific tastes, competences, motives, aspirations, political prejudices, and the rest, and they assume that morality, technology, science, and economy will evolve in particular ways. A large part of the work of innovators is that of "inscribing" this vision of (or prediction about) the world in the technical content of the new object. (1992, p. 208)

IS design, therefore, is an attempt to predetermine both the settings that users are asked to imagine for a particular piece of technology, and to distribute their roles properly. These two processes embed rules and resources for technical and nontechnical users (Akrich, 1992; Orlikowski, 1992). The design defines technical and nontechnical users with specific competency, morality, and ethics, as well as the space and the ways in which they are supposed to act (Akrich, 1992; Callon, 1991; Latour, 1992). Once defined, roles could be distributed to users as a function of the effort required to perform tasks (Latour, 1992; Law & Bijker, 1992). According to this logic, it would be useless to delegate tasks to artifacts or people if the effort of making sure that they perform as they ought would be greater than the original effort (Law & Bijker, 1992). For example, computers are good at handling routine and repetitive tasks; letting humans handle them would not be appropriate.

Users may not subscribe to the rules and resources of IS designs as envisioned by designers—ISs take on their true forms during their interaction with users in the actual use context (Akrich, 1992). Use contexts are complex and involve multiple internal and external actors that shape IS designs. In general, the designs and the uses of ISs are continuous sociotechnical processes that emerge in unpredictable fashions from complex interactions between the social and the technical (Cordella, 2006; Markus & Robey, 1988). For example, in her seminal work, Lynne Markus shows how the misaligned interests of different user groups in a corporation influenced the adoption of an MIS, demanding role-enactment and distribution changes (Markus, 1983). In developing countries like Ethiopia, where the research for this article took place, donors are the primary funders of various programs in the health sector, including those addressing HIV/AIDS, malaria, tuberculosis, etc. As such, they play key roles in most change initiatives, including the introduction of ISs. The developing-country health sector in general is complex and highly political (Braa et al., 1995; Braa et al., 2004).

In order to explicate the designs of ISs, it is important to consider the emergent and sociotechnical perspectives. In this regard, actor-network theory (ANT) offers the language to deal with emergent sociotechnical changes by giving due emphasis to IT artifacts (Holmström & Robey, 2005; Monteiro, 2000). ANT traces its origin primarily to the works of Michel Callon, Bruno Latour, and John Law, the scholars who initially developed the theory to help understand the sociology of science. Later applications of ANT focused on technology, and some even included IT (for a detailed review, see Walsham, 1997). The theory has become popular and relevant to the study of IT in organizations, and at times, it is used to guide empirical research on IT (Gao, 2005; Holmström & Robey, 2005; Mitev, 2009; Rose & Jones, 2005; Tatnall & Gilding, 1999; Walsham, 1997). According to ANT, social and technical stability reside in the mutual dependency between the technological properties and the social context. It deals with the social-technical divide by denying that purely technical or purely social relations are possible (Tatnall & Gilding, 1999). Heterogeneous objects only exist on the surface; in reality, everything consists of complex relations made up of both social and the technical elements. Because ANT sees the social and the technical as inseparable in this way, it argues that people and artifacts should be analyzed with the same conceptual apparatus

Table 1. Description of ANT Concepts Adopted in This Research. (Adapted from Walsham, 1997).

Concept	Description
Actant (or actor)	Both human beings and nonhuman actants, such as technological artifacts
Actor-network	Heterogeneous network of aligned interests, including people, organizations, and standards
Enrollment and translation	Creating a body of allies, human and nonhuman, through a process of translating their interests to be aligned with the actor-network
Delegates and inscription	Delegates are actants who "stand and speak for" particular viewpoints that have been inscribed in them, e.g., software as frozen organizational discourse

(Callon, 1986b). ANT attempts impartiality toward all of the elements in consideration, whether human or nonhuman, making no distinction in its approach between the social, the natural, and the technological. It uses the term "actant" to refer to both human and nonhuman network participants. This symmetric treatment of people and technologies has been the primary focus of ANT's critics. However, it should be pointed out that ANT does not deny differences among actants; instead, it is against formulating a priori distinction and hierarchy among them (Callon & Latour, 1992; Walsham, 1997).

This research is particularly interested in the notions of actant, actor-network, inscription, and translation, which are described in Table 1. An actor-network is a heterogeneous network of aligned interests that link together actants of different types and size (Callon, 1986a, 1986b, 1991; Latour, 1991). An actant is not just a "point object"; it is an association of heterogeneous elements themselves constituting a network. As such, each actant is also a simplified network (Law, 1992; Tatnall & Gilding, 1999), a single, black-box entity that hides other actants or a network of interactions and associations until it is, itself, unpacked (Callon, 1986a; Law, 1992; Tatnall & Gilding, 1999). Hence, ANT gives the flexibility to zoom in and out on sociotechnical ensembles at different levels of granularity (Monteiro, 2000).

The stability of an actor-network would be preserved through the processes of translation and inscription, by which actants' diverse interests become aligned with each other and embedded into technologies (Callon, 1991; Gao, 2005; Holmström & Robey, 2005). Translation refers to the mechanisms through which actants transform themselves, displacing their own identities, as well as those of others (Bruun & Hukkinen, 2003; Callon & Latour, 1981). It implies definition and involves a translator, something that is translated, and a medium in which that translation is inscribed (Callon, 1991). Translation involves enrolling activities into the network, and then controlling them to define the power that actants have in relation to others (Heeks & Stanforth, 2007). Power, in this case, is about the ability to produce and achieve collective goals (Silva, 2007). Drawing upon these notions of ANT, this research explores the trajectories of an IS design over time and location to understand their effects on adopting organizations and sustainability. To do so, the next section describes the research context and methods.

3. Research Context and Methods

3.1 Context

This research was conducted in Addis Ababa, Ethiopia, during the development and implementation of ARTIS in ART clinics. HISP initiated the ARTIS project in 2006 as part of its global R&D initiative, which was aimed at designing, implementing, and sustaining HISs in and across developing countries, using open source software (OSS) (Braa et al., 2004). ART aims to reduce the mortality rate, improve the quality of life of AIDS patients, and reduce the burden they place on society (FMOH–Ethiopia, 2005). Having reported the first two HIV cases in 1986 (FMOH–Ethiopia, 2004), Ethiopia had lost about 900,000 lives to AIDS by 2003 (FMOH–Ethiopia, 2006). The annual death rate (until 2005), the number of new HIV infections, and the country's ART needs have been increasing year after year. For example, the number of patients who needed ART in 2004 was about 278,000, and it was projected to

increase to 350,000 by 2010 (FMOH–Ethiopia, 2006).

The success of ART is closely linked to geographic coverage and patients' adherence to regimens. An adherence level of more than 95% (missing no more than one dose per month) is required for patients to receive the therapy's hoped-for benefit (FMOH–Ethiopia, 2005). Poor adherence facilitates the development of drug-resistant viruses, harming not only an individual patient's prospects, but also the community's as a whole, because transmission of a drug-resistant virus can ultimately lead to a superimposed epidemic of drug-resistant HIV.

To facilitate ART, especially in data collection, management, and analysis aspects, the FMOH (Ethiopia's Federal Ministry of Health) had developed data collection and reporting forms, along with guidelines for how they should be filled out and by whom. The guidelines and forms dictate the collection of large amounts of data per individual patient, as well as duplication of them in different forms. These tasks were making accurate data collection, as well as the analysis and evidence-based service that follows from it, inordinately challenging. This became increasingly the case as the numbers of patients grew and the setting became more and more resource-constrained (Mengesha, 2007). Stakeholders of the service at different levels had difficulties getting accurate information on time, so they were unable to plan and make informed decisions. HISP felt that introducing a computer-based IS (ARTIS) would alleviate these challenges, so it initiated a project aimed ultimately at realizing an HIV/AIDS management system that could also integrate a wide range of related services (Mengesha, 2007).

Though HISP and other local and international organizations were supporting ART, the Ethiopian federal government had mandated that four U.S.-based universities should provide the technical support for ART in Ethiopia. In 2003, the United States Congress approved the President's Emergency Plan for AIDS Relief (PEPFAR), an American initiative to combat the global HIV/AIDS epidemic which allocated US$15 billion over five years to combat HIV/AIDS, primarily in 14 focus countries, including Ethiopia. Following PEPFAR's approval, the Ethiopian bureau of the Centers for Disease Control and Prevention (CDC), the U.S. government entity responsible for all federal HIV/AIDS funding allocated to Ethiopia, invited and selected four American universities to provide technical support for the prevention and control of HIV/AIDS in Ethiopia. The universities were responsible for enhancing ART, developing human resources in HIV/AIDS care, and strengthening HIV/AIDS-related information systems. The second installment of PEPFAR authorized up to $48 billion for fiscal years 2009–2013.

The government of Ethiopia divided the country into four parts and gave one part to each university, demanding that all other organizations involved in ART align their activities accordingly. However, the non-existence of a coordination mechanism had created an environment conducive for the different organizations to take their own trajectories of supporting ART, especially when it came to introducing ISs. The interests of different organizations in addressing the same problem with different, but similar, solutions turned the environment into one of competition, power struggle, and politics, rather than of collaboration (Bradshaw-Camball & Murray, 1991), a phenomenon that influenced the development and implementation of ARTIS.

3.2 Methods

The research adopted the qualitative research approach (Silverman, 2005), with the underlying epistemological and ontological concepts of interpretive philosophy (Klein & Myers, 1999; Orlikowski & Baroudi, 2002; Walsham, 2002). To make sense of the development and implementation of ARTIS, it was essential to understand the intersubjective meanings and actions of actants in the ARTIS sociotechnical network. This was accomplished by examining contextual factors, and after those, the interpretative philosophy and the case study methodology (Yin, 2003), all through the lens of actor-network theory. That emergent perspective has been advocated by various researchers as a more viable means for understanding the interplay between organizations and ISs than deterministic frameworks, which hew to the notion that the uses and consequences of ISs emerge unpredictably from complex social interactions (DeSanctis & Poole, 1994; Kling, 1980; Markus & Robey, 1988; Robey & Boudreau, 1999). To focus on the dynamics, the process theory of studying change is preferred over the variance theory (Markus & Robey, 1988; Tsoukas, 2005). This study was therefore conducted in accordance with the emergent perspective and process theory.

Table 2. Respondents by Specialization and Frequency.

Specialization/Responsibility	Number of Respondents	Number of Interviews and Discussions
ART coordinators	5	5
Physicians	5	5
Nurses	5	5
Data clerks	8	12
Regional health bureau officials	3	8
Representatives from U.S.-based universities	2	7
Developers	3	6
National HAPCO	1	2
Total	32	50

The research employed interviews, on-site observations, formal and informal discussions, and document-review to collect data. As a member of the HISP network, the author of this paper was intensively engaged in the development, implementation, and rollout of ARTIS. He carried out field study March–August 2006, February–April 2007, and November 2007–February 2008. In these time periods, the researcher studied publications of the FMOH, surveyed and observed the work processes of ART clinics in five hospitals (Armed Forces and Military General Hospital, Tikur Anbesa Teaching Hospital, Zewditu Memorial Hospital, Federal Police Hospital, and Federal Prison Health Center), and interviewed and held formal and informal discussions with the coordinator, physicians, nurses, and data clerks in the pilot clinic. He also held several formal and informal discussions with health bureau officials in charge of ART in two regions besides Addis Ababa (Amhara and Oromiya), with the national HIV/AIDS prevention and control office (HAPCO), and with two universities involved in the government's ART mandate, all in an attempt to roll out ARTIS and learn about other initiatives. Altogether, a total of 50 interviews and discussions (formal and informal) were conducted, as shown in Table 2.

During each interaction, the researcher took notes and summarized main points soon afterward, occasionally presenting reports to HISP coordinators and other actants. These interviews, as well as the subsequent analysis of the ARTIS design that followed, were spaced throughout the timeline of the ARTIS design process, adding a temporal perspective to the data gathered.

The analysis was centered on the pattern of iteratively reading data, identifying key themes, and then relating them to the conceptual framework. There was a need to go back and forth between the design of ARTIS, the standard practice, and the local practices of ART clinics to understand differences, gaps, and changes in role delegation and the interests of the actants as they occurred chronologically in the ARTIS development (Akrich, 1992). Subsequently, the findings of the analysis were interpreted in light of concepts drawn from ANT and the IS literature.

4. Development and Rollout Processes of ARTIS

ART service in Ethiopia starts by recording demographic and clinical details of AIDS patients on an intake form. Any later encounter of a patient with the clinic is recorded using a follow-up form. Filling out patient information on both forms falls under the responsibilities of physicians and nurses. After each encounter, data clerks copy data from both forms into pre-ART and ART register books, and later, aggregate and report to various recipients using pre-defined pre-ART, ART, and regimen reporting forms at different frequencies.

As indicated in Figure 1, based on the guidelines of the FMOH, many mandatory fields are duplicated, both on different pages of the same form and across forms. The intake form, for example, has seven pages, with 25 fields on each page, out of

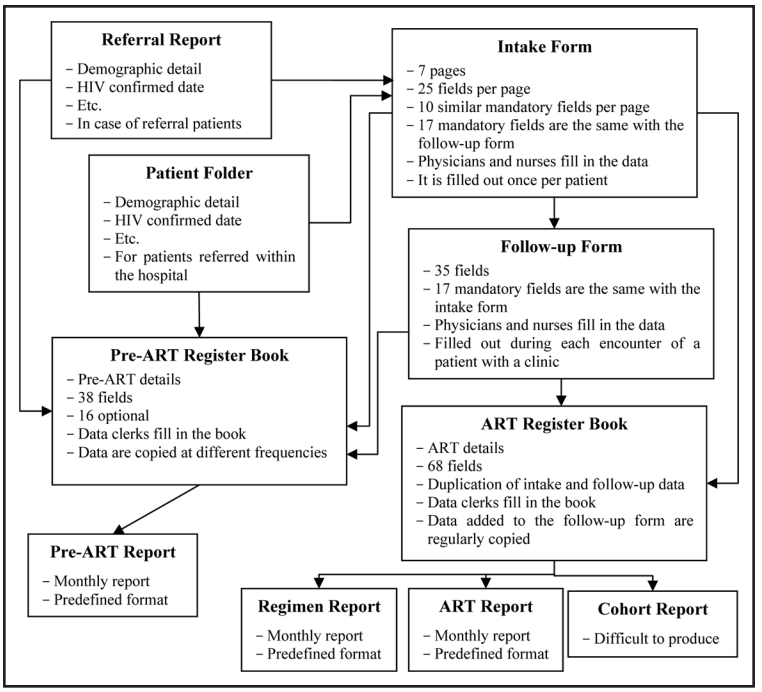

Figure 1. Dependencies among data collection and reporting forms of ART clinics in Ethiopia.

which 10 of them were similar, mandatory fields repeated in all of the pages. Then, 17 of the mandatory fields were duplicated on the follow-up form. Furthermore, the fixed-format reporting forms did not have room for new regimens, despite their existence in practice. The identification of patients with specific appointment dates proved challenging, and as a result, follow-up was not possible. Each surveyed ART clinic had a PC with MS Office applications installed, though they did not have a computer network or an immediate plan for either networking or sharing ART data across physicians or clinics in real time. The data clerks use MS Office applications to finalize reports after collecting and analyzing data manually. HISP has introduced ARTIS to curb some of these problems. The following sections describe its development and rollout processes.

4.1 ARTIS Development

HISP approached the Addis Ababa Health Bureau (AAHB) in 2006 and proposed the development of ARTIS as a solution for the drawbacks of the manual system and to facilitate evidence-based service (Mengesha, 2007). The person in charge of ART in AAHB reiterated the challenges they were facing due to the manual system and agreed on the proposed solution. Following the agreement, HISP and AAHB identified a pilot clinic, assuming that all ART clinics would follow similar data collection and collation procedures, as prescribed by the FMOH. The identified clinic had several attributes that made it stand above others in the selection process: It started ART before others, it served relatively large numbers of patients, data collection and compilation were particularly difficult as a result, it had the experience of dealing with a similar but failed attempt at revamping the ART system, the staff had better experience, etc. The local developers in the HISP network studied the work processes of the pilot clinic, and then designed and developed an open source (von Hippel & von Krogh, 2003) ARTIS with the financial and technical support of HISP.

ARTIS was developed using open source technologies (MySQL, Apache, and PHP), has a Web-based interface, and runs in both standalone and networked environments. It exhibits local features, including the Ethiopian calendar and the (nationwide) "standardized" data collection and reporting forms and procedures. Due to these features, it was labeled a "state-of-the-art IS." The developers stated:

> Our system bases the OSS license and state-of-the-art open source technologies. Any ART facility can use it free of charge and we have been offering our services freely. We have a plan to upgrade the system in collaboration with our international partners to make it more robust. (May 2006)

Most of the manually filled-out forms in the pilot clinic were incomplete, and the unique identifier was missing in some of the cases. Given this incomplete data, designing the computer system to enforce automatic data validation, such as data existence, domain, range, and format verifications, was

not possible. If this had been done, those records with missing and wrong values, which were many in number, would not have been entered into ARTIS, hindering the system once it was implemented. As a solution, data validation—value existence, domain, range, and format checking—was delegated to data clerks rather than the computer system.

The manual system in the pilot clinic had undergone changes to the standard procedure of data collection, and had introduced new forms. For example, the data clerk was supposed to copy a patient's information directly from intake and follow-up forms into either pre-ART or ART register books. Due to the large number of patients, it had become difficult for the clerk to go through all the intake and follow-up forms for every patient and copy the data into pre-ART and ART register books. In response to this overload, the clinic had developed an abridged version of the follow-up form and asked physicians to fill in both forms with the same data. The abridged version was more convenient to collect and enter data into ARTIS than the original form, but ARTIS had been designed to the FMOH standards, so it was configured for the original follow-up form, not the abridged version.

While HISP was developing ARTIS, some of the mandated organizations and others were commissioning individual- and organization-based IS approaches, though not all of these attempts and plans bore any fruit. As part of its effort, HISP had negotiated with the university teams, the FMOH, the national HAPCO, and other regional health bureaus, demonstrating to them the nature, features, and capabilities of ARTIS. However, these efforts did not bring all of the actants on board the pro-ARTIS network, especially the FMOH, HAPCO, and two of the mandated universities. The developers stated the following:

> We have demonstrated our system to different regions at different levels. We have learned that our system satisfies the needs of the end-users. We have support from the regional health bureau and end users. Nevertheless, those who are responsible for supporting ART service at a national level and those USA Universities do not support us. . . . They are trying to develop and introduce their own system. (February 2007)

HISP considered adding new functions to ARTIS, which could show the strength of local capacity and increase the applicability and importance of ARTIS, leading perhaps, in turn, to winning the competition. As a result, the developers added some functions that were not readily available in the manual system, but were desirable for ART. For example, follow-up is core in ART, but the manual system did not support it well. Having an appointment management function and more report/analysis generation capabilities would better facilitate follow-up and improve the quality of ART. Being shown the updated ARTIS, an AAHB official who had tremendous difficulty identifying stable patients using the manual system was able to do so with just a few mouse clicks using ARTIS. He stated the following:

> I am very happy with the feature and functionality of the software. Besides, it does not involve us much cost. . . . Really it is very interesting to easily identify those patients who are stable using the system which otherwise could be time-consuming and cumbersome. (March 2007)

At this stage, other organizations had already developed a similar IS and implemented it in another region, and were planning to implement it in Addis Ababa as well, despite the fact that HISP's ARTIS was in place there. After evaluating all the competing ISs, the AAHB decided on HISP's ARTIS as the winner, insisting on expanding its implementation in Addis Ababa. The decision was not received well by some individuals in the national HAPCO, since they were supporting other developers. The situation highlighted the challenges of gaining acceptance on a national level and implementing a system developed in one place in other regions. The implementation of ARTIS in other regions depended on the consent of the mandated organizations—consent they were unwilling to give at the time. This situation was evident when the IS was brought to the Oromiya region, as the person in charge of ART stated:

> [W]e prefer to use your software than the one introduced by [the other actant]. We have seen both; yours has better functionality than the other one. Nevertheless, [the other actant] has the mandate in our Regional State to support ART . . . the agreement was made at the Federal Government level. . . . However, we keep on discussing with the concerned people on this matter. (April 2007)

HISP presented ARTIS at various local and international conferences in the presence of several

Table 3. Actants and Their Interests in the ARTIS Development and Implementation Process.

Actant	Description	Interests
Standard ART Practice	The FMOH has developed standard forms and guidelines for collecting, analyzing and reporting ART data.	The standard forms and guidelines remain intact unless changed by the FMOH.
ART Clinics	This group refers to the local practices of ART clinics that exhibited differences in data collection procedure and forms.	Work practices of clinics required ARTIS to follow their path, affecting role distribution to users.
HIV/AIDS	HIV/AIDS affects a large population and demands preventive and curative measures. AIDS patients require lifelong treatment and medication.	ART demands huge amounts of data collection, analysis, interaction with related services, and a high level of adherence and close follow-up.
AAHB & Donors	AAHB allocates resources and supervises ART clinics, and had limited IT experts and financing to develop or buy ISs. Donors are those who were supporting ART and receiving reports.	This group was interested in making informed decisions and plans. They required accurate information on time and in the required format.
HISP	HISP is composed of developers/students and researchers linked together in a south-south and north-south network of R&D activities. HISP set the stage for the development and implementation of ARTIS. The Ethiopian chapter of HISP was based at Addis Ababa University.	HISP wanted immediate entry into and domination of the ART-IS market. Wasting time was associated with detaching from ART. Developers were students and had little time. The push by others to develop a similar system was considered a threat.
ARTIS	ARTIS is an OSS-based data collection, management, and analysis IS developed by HISP. It runs in both standalone and networked environments, has a Web-based interface and adheres to the local context.	ARTIS alleviates the challenges of manual collection, management, and analysis of ART data. To realize its benefits, the IS should get support and run in the clinics.
Mandated Universities	These are the four universities from the United States that were empowered by the Ethiopian federal government's mandate to provide technical support for ART in Ethiopia.	They needed to introduce their own ISs. Some of them had already commissioned individuals and companies to develop an IS similar to ARTIS.
Others	This category includes organizations that did not have the backing of the government's mandate, but still supported other ART system development initiatives.	Using their informal influence in the FMOH, they wished to introduce another IS than ARTIS.

actants, including regional representatives, the FMOH staff, and others. Although regional health bureau representatives were happy with ARTIS, with the development and implementation arrangement, and above all, with its open source characteristics, the FMOH staff was not interested in using ARTIS. Through EFOSSNet (Ethiopian Free & Open Source Software Network, a group of ICT specialists promoting OSS), ARTIS and the activities of HISP were introduced to the wider OSS community in Ethiopia. EFOSSNet extended its support, and some of the members expressed their interest in working on the project, although that assistance never materialized. Table 3 summarizes the interests of the actants involved in the development of ARTIS.

4.2 Rolling Out ARTIS

Following the decision of the AAHB, ARTIS was rolled out to three other clinics in Addis Ababa. Once there, one of the mandated organizations that had not commissioned the development of a similar system agreed to test ARTIS in its sites while negotiation with the other three was continuing. As a result, ARTIS was implemented in another two clinics—Federal Police Hospital and Federal Prison

Health Center—but their procedure was found to be different from that which was used at the pilot clinic. Due to age and patient volume, the pilot clinic had introduced a unique data collection procedure that could not be replicated by the other, similar clinics. For example, the pilot clinic had started offering ART before the introduction of intake forms, and data had been recorded into pre-ART and ART register books solely from follow-up forms. The clinic had piles of filled-out pre-ART and ART register books without corresponding intake data. Consequently, the developers delegated the role of accepting data from pre-ART and ART register books and intake forms to the system, and that of populating the pre-ART and ART register books to human users.

Those ART clinics that started ART after the introduction of intake forms no longer needed to enter data into ART and pre-ART register books from the keyboard. Once data from intake and follow-up forms were entered into ARTIS, ART and pre-ART register books could be generated as reports, eliminating the need to reenter the same data, but requiring an update to the ARTIS system design. Hence, in the interests of data accuracy and bypassing human limitations for new patients and patients who had intake data, the system was modified such that it now delegated the role of populating pre-ART and ART register books to the computer system itself, rather than to data clerks. Figure 2 summarizes the context, the dynamics, and the resulting ART system.

The new ART sites started the service relatively late and had fewer than 100 patients. The fairly small patient population made incomplete or invalid data correction somewhat easy, and with that assumption, the developers delegated the role of data validation to the computer system. Although a role that had belonged to the data clerks was being delegated to the computers, similar to the original pilot clinic, this re-delegation was occurring in a completely different setting. Even if this procedure facilitated data entry and improved data accuracy, it did not impact the design of ARTIS at the pilot clinic, but rather, it initiated a project that was intended to cleanse erroneous data.

As of 2009, ARTIS has been implemented in 27 ART clinics in Addis Ababa, and one of the mandated universities has developed and tested a similar system in another region. Another university has clearly decided not to collaborate with ARTIS, while the other two are testing ARTIS's capability in the sites where they are responsible. Some of the non-mandated organizations still need to develop their own system, and they have yet to show any product.

5. Analysis and Discussion

The development and implementation of ARTIS had established a network of aligned interests among the standard ART practice, HISP, ART clinics, AAHB, and HIV/AIDS. A counter-network (Braa et al., 2004; Castells, 2000) was comprised of the same non-human actants and the mandated organizations (and others) seeking to develop similar, but competing, initiatives. The counter-network was supported by individuals in the FMOH and the national HAPCO. In the course of addressing the data collection, analysis, and reporting needs of ART clinics; ensuring continuity of the sociotechnical network of aligned interests; and counteracting the counter-network, the material form and functions of ARTIS, along with the sociotechnical arrangements and development processes, embedded certain features. This section analyzes and discusses these change processes and the interests of actants as they were translated and inscribed into ARTIS, all in relation to the implementation context and the IS literature.

5.1 Inscribed Interests and Future Trajectories

ARTIS, as an inscription, embedded the interests of some of the actants and some contextual matters. The design of ARTIS considered the nationally standardized forms and guidelines despite their problems and avoided introducing a new form, despite its importance. ARTIS's adherence to these standards and the local calendar was a prerequisite for its adoption. Along with those features, the Web-based interface, OSS characteristics, and the capability to run on both standalone and networked computers boosted ARTIS's usefulness and potential.

Take the Web-based interface, for example: ART services would benefit greatly if all users had online access to patients' data, with the support of analytical and visual tools, at any time and from any place. The ARTIS design makes this possible by combining the power, simplicity, and flexibility of Web interface with network capability.

Other design elements were also used as strate-

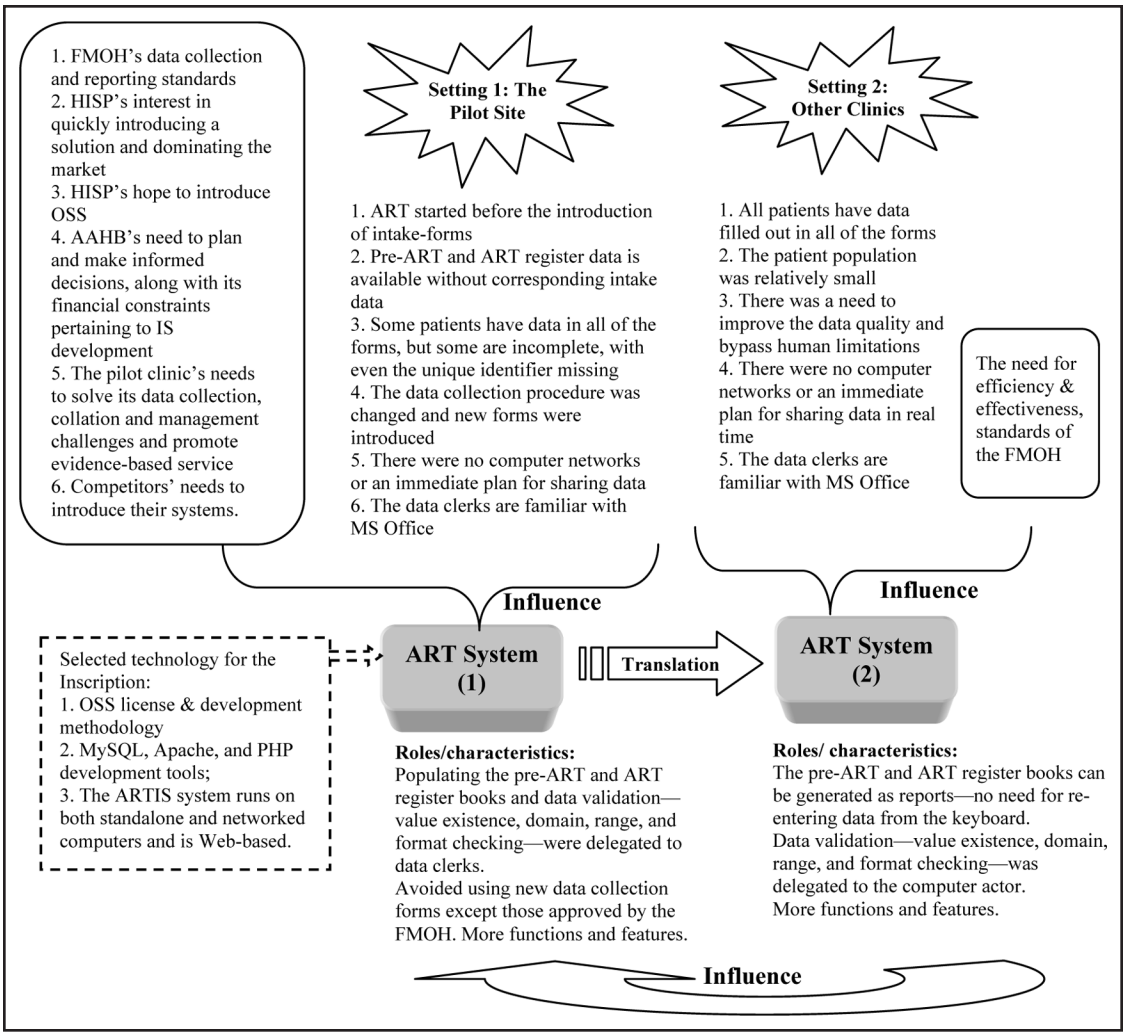

Figure 2. Graphical representation of influences, translations, roles, and their interrelationships.

gies for establishing and sustaining the socio-technical network. The OSS approach, for example, attracted EFOSSNet (a local network of OSS promoters), AAHB, and international partners in the HISP network. Despite its aspirations to realize evidence-based ART service, AAHB had significant financial limitations, so a no-cost license for ARTIS was in accordance with the interests of AAHB. In addition to the software, HISP had extended free services to ARTIS users throughout the implementation process, such as installation, enhancement, maintenance, training, etc.

The above features of ARTIS specify not only the current patterns of use and the ART service, but also future patterns and expected modes of operation. The current technical standards and protocols of ARTIS, including the network, database, and interface, as well as the OSS ideology, would resist future counter changes. The strength of these technical and ideological elements to resist counter changes would not come just from the elements themselves, but from the network built around them. For example, due to the involvement of various governmental, nongovernmental, national, and international actants of different type and size in promoting OSS adoption serving as poly-vocal systems (Chan, 2007), in general, and the academics, EFOSSNet, HISP, developers, and beneficiaries in the ARTIS case,

the OSS ideology would resist future counter changes.

Analysis of features and functions of ARTIS in relation to the implementation context suggest that HISP introduced them mainly to gain negotiation power over the counter-network, and to build alliances with partners. Although the use of OSS ideology helped to form alliances, the idea was not mature in Ethiopia, and its aspired-to importance had not yet been practically established in developing countries. In fact, there has been an ongoing debate on the matter (bridges.org, 2005; Weber, 2003; Weerawarana & Weeratunge, 2004). ART clinics did not have networked computers or an immediate plan for sharing data across users (physicians, nurses, clinics, etc.) in real time. In practice, the capability of ARTIS to run both on standalone and networked computers had negative implications on the speed and storage space of computers. So far, ARTIS has been running on standalone computers, i.e., all the required technologies were installed on the PCs themselves. To avoid the speed and storage problems, those programs should be installed on servers instead. In effect, the non-availability of a computer network slowed down PCs and increased the demand for data storage, a problem that was difficult to solve, considering the resource-constrained setting. ARTIS could have been developed using technologies with which the end-users were already quite familiar, but which may not have been helpful in interesting other actants and bringing aboard the network. For example, the use of MS Office applications would be sufficient to address the problem, but doing so would imply cost and could downgrade ARTIS technology-wise and reflect mediocrity on the skill and knowledge of the project developers, ultimately posing difficulty to winning the competition. Considering such matters was not worthwhile. By doing so, HISP and the developers played the roles of economists, moralists, and political scientists at different moments in the course of the project (Callon, 1991).

HISP had devised diverse strategies to interest other actants and forge alliances besides exploiting the technological and ideological opportunities discussed above. The lack of indigenous technological capability has been one of the bottlenecks of IS implementation successes in developing countries (Avgerou, 2008; Heeks, 2002). To develop and sustain local capacity, HISP chose to base the development of ARTIS in the local environment, to endow local developers and users with knowledge and skill through formal and informal education, and to establish local and international networks so that developers could share expertise and resources. The effectiveness of this arrangement was proven when an official from AAHB requested a new program function and was satisfied with the result. Feature and function addition was crucial to gaining the support of beneficiaries (data clerks, physicians, coordinators, and other officials), since it boosts both the usefulness of ARTIS and its reliance on local capacity.

HISP's need for domination was addressed through being mindful of local contexts, using technologies and an ideology that attracted others, adding more functions, offering free services, and yet compromising on speed and data-storage requirements. The focus on local capacity-development, as well as on networking actions within and outside of the nation, both assured continuity and boosted the beneficiaries' reliance on the sociotechnical arrangement. The interests of other organizations to introduce a similar system, as well as the fact that some of them had the mandate to do so, were translated into the use of "better technologies, enhanced features and functions, suitable ideology, etc."

In this case, HISP was the dominant actant that insisted upon the definition of both the problem and the solution (Law & Bijker, 1992). HISP follows the political agenda of boosting users' capacities and sustaining implementation through networking actions within and across developing countries, as well as between the developing and developed worlds, of iterative incremental development and implementation processes, of interesting others over time, of OSS use, etc. (Braa et al., 2004). These strategies of HISP's were embedded in the established sociotechnical network of ARTIS. Generally, the HISP agenda of change and sociotechnical order-formation were embedded not only in ARTIS, but also in the wider sociotechnical arrangement. In principle, the mandated organizations have power over others to support ART, but in practice, HISP was more powerful than others because of its capacity to define or redefine what holds everyone together, form alliances, and produce and achieve collective goals.

5.2 Role Delegation

Role delegation to actants in the ARTIS sociotechnical network was influenced by the work practices of the pilot clinic and the need to sustain the network. HISP's interest in quickly introducing a solution, as well as the assumption that all clinics would operate similarly, in keeping with the FMOH guidelines, influenced the design and development of ARTIS by stressing a primary focus on the work practices of the pilot clinic. This decision has ultimately resulted in a design that imitates the work practices of the pilot clinic, i.e., the development of a path-dependent system that delegates rules and resources according to the pilot clinic's model (Hanseth, 2004). The initial design of ARTIS therefore dictated that users should enter data into an intake form and register books from a keyboard and generate reports from register books. This practice obscures the need for inputting intake and follow-up data unless they are used. It further compromises data and report quality because of the method's susceptibility to errors due to double copying—first, from intake and follow-up forms into register books, and second, from register books into ARTIS. It is not possible to produce reports directly from the intake and follow-up data, because intake data are missing for some patients who started ART with the clinic before the introduction of the intake form.

Furthermore, due to the need to ensure continuation of the established sociotechnical network, developers delegated some tasks to humans that a computer system could have performed more effectively and efficiently. Computers are superior to humans in consistently and efficiently carrying out structured and routine tasks, such as validating data availability, domain, range, and format (Kling, 1980). However, the task of data validation was delegated to human users in the case of ARTIS because of the need to sustain sociotechnical order. Given the size of incomplete data, enforcing automatic data validation would have hindered the usability of ARTIS and disturbed the sociotechnical order. The situation is an example of a time when role allocation could not be a function of the effort required to perform tasks (Latour, 1992; Law & Bijker, 1992). Rather, it could be a function of the negotiation and compromise between data quality and the overall sustainability of a sociotechnical order. In this case, actants in the sociotechnical network negotiated acceptable levels of data accuracy and service—levels that were agreed upon socially, but were neither technically nor formally perfect.

The implementation of ARTIS in another two clinics triggered design changes that were related to role delegation. The tasks of data validation and filling out register books, which initially were delegated to human beings, were now given back to the computer system. As indicated in Figure 2, the original design of ARTIS was modified so that it would automatically generate pre-ART and ART register books and validate data, a model in line with the "effort" logic of role allocation. As an efficient and effective tool to perform data validation, the computer system, a nonhuman actant, dictated design changes. ARTIS did not move to the new sites as it was, but changed according to the new contexts—simultaneously changing these new contexts, themselves. The enrolling and controlling processes facilitated the expansion of the ARTIS network through translation of interests, assuring its continuity. This occurrence also reveals that the same task was delegated to human and nonhuman actants at the same time, but in different contexts. Delegating the same task to human and nonhuman actants means equally delegating force, duties, and ethics, which would imply competency.

The role allocation dynamics were crucial to sustaining the ARTIS sociotechnical network and, hence, to its implementation. Still, they brought obstacles to achieving the goals motivating the introduction of computer-based ISs, namely enhancing efficiency and effectiveness. As an example, crafting the system to accept pre-ART and ART register books from keyboard input duplicates data, demands additional data storage, requires resources for verifying and entering data, and impacts computer speed and data management efficiency. It is also inconvenient to generate reports because of the difficulty of choosing the source—either register books or the intake and follow-up forms. Besides, the problem of accurate information generation could be amplified by the lack of appropriate data-validation mechanisms. Errors during data collection or at the time of data entry could lead the two data sources to exhibit differences, ultimately resulting in two different reports recommending completely different actions. This phenomenon highlights the deficiencies of IS designs that hamper improved decision-making and organizational effectiveness. The fact that the impact of the role allocation dynamics

on the end result of the IS was negative underlines particularly dramatically how important it is to apply frameworks—in this article, actor-network theory—that enable us to examine these dynamics in depth.

As indicated so far, the development and implementation of ARTIS in ART clinics in Addis Ababa was shaped by the nature, features, and capabilities of ARTIS; the social and political processes; and the capacity development strategy, as well as by an approach that transcended the local/global dichotomy by blending local and global experts in the HISP network. The future of ARTIS and the sociotechnical network thus depend a great deal on both the flexibility and technical capacity of ARTIS, as well as on the complex social and political environment.

6. Conclusion

The research reported in this paper investigated the interests of actants embedded in the material and functional forms of an IS, their translations, their negotiations in sociotechnical order formation, and the IS's overall sustainability—all considered in a resource-constrained setting where competition and politics were paramount. By studying the design dynamics of an IS over time and space following an interpretative approach, the research demonstrates how the material and functional forms and the resulting sociotechnical network embody the interests, ideologies, and strategies of the dominant and powerful actant—the actant that defines both the problem and the solution, and produces and achieves collective goals—despite obstacles presented by the realities of implementation contexts. The embedded interests and features specify the current and future patterns of use of the IS, the capacity-development strategy, and the nature of current and future changes expected from adopting organizations. The features could be resistant to future counter-changes not because of their inherent strength, but due to the magnitude of actants that would stand and speak for them.

In a resource-constrained, competitive setting, choice of development technologies and ideology, role enactment and distribution, and feature and function additions aim mainly to excel others and define and reinforce a sociotechnical network at the expense of improved performance, decision-making, and organizational effectiveness. Dynamism in role-allocation to human and nonhuman actants, regardless of the effort required to perform the roles, for example, was essential to sustaining the ARTIS sociotechnical network, but negatively impacted informed action and organizational effectiveness. Generally, this article demonstrates that, besides addressing the primary goals of their existence, ISs carry the interests of actants, as well, and that those interests can impact performance and the future behavior and structure of organizations, and can specify the current and future environment in which the ISs will be running and the functions they can provide to current and future users, regardless of the use context.

As demonstrated in this research, actor-network theory is a powerful methodological tool used to guide identification of actants and their associations at flexible levels of analysis. Actor-network theory also supports understanding and interpretation of the mutual interactions between the social and the technical by offering the language and flexibility to zoom in and out on actants at different levels of granularity, and through symmetric treatment of the social and the technical. As has been shown, social and technical stability resides in the mutual dependency between the technological properties and the social context, something that ANT offers the language to explain.

This research suggests that IS development and implementation is a complex sociotechnical activity in which the social and the technical negotiate and evolve together. It also demonstrates that donors and their agendas play significant roles in IS development in developing countries, especially in the healthcare sector. The findings also suggest that system developers should consider the work practices of other, similar organizations, regardless of any standards that may be in place, as contextual factors do influence local practices. Furthermore, system development, besides negotiating local interests, should pave the way for the development of generic systems that could be used across settings (Pollock et al., 2007), especially where there are standards for operations. The existence of standard operational forms, guidelines, and procedures increases the similarity of practices across settings. In cases where adherence to such standards is a must, ISs should be generic enough to be used across a diverse range of organizational contexts. Therefore, developers should deal with tensions between the local and the global, so as to develop more generalizable systems. ■

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