Infrastructuring Work: Building a State-Wide Hospital Information Infrastructure in India

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Information and communication technologies that strengthen knowledge-based governance in low and middle-income countries (LMIC) will affect work processes and organizations on a massive scale. This paper draws attention to demands on public sector organizations in resource-constrained contexts that face different challenges than in high-income societies. This paper from the Indian public healthcare sector reports on design, development, implementation, and scaling of a free and open-source software-based hospital information system for district hospitals. The paper focuses on the implications for work, competencies, and organization, building on and extending the concepts of “automate” and “informate.” The paper focuses on the emerging and recursive interplay between information infrastructure and work within the context of organizational realities of a district hospital in an LMIC context, captured by the concepts of “infrastructuring of work” and “work of infrastructuring.”

Keywords: information systems and organizational change; inter-organizational information systems; management of IS projects; action research; health; India; developing countries

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1. Introduction

Relationships among information, technology, work, and organization have defined the information systems (IS) field since its inception. With notable exceptions (e.g., Gasser 1986, Barley 1986, Zuboff 1988, Yates 1989, Orlikowski 1993, Barrett and Walsham 1999, Boudreau and Robey 2005), much IS research has focused on the level of the organization and has glossed over “work” as a concrete activity (Barley and Kunda 2001). Current debates around the relation between human and material agency tend to discuss work tangentially, often as empirical illustrations rather than focal themes (see, e.g., Orlikowski 2007, Leonardi 2011). Ethnography-inspired work practice studies in computer supported collaborative work (CSCW) (Schmidt 2011, Schmidt and Bannon 2013, Blomberg and Karasti 2013) provide rich insights into technologies, work, coordination, and organization (Orlikowski and Barney 2001, Barney and Kunda 2001), but tend to focus on small groups and experimental technologies rather than large-scale, interorganizational systems (Monteiro et al. 2013), and these analyses have not been carried out in low and middle-income countries (LMIC) contexts. There is a dearth of research on how information technologies impact work on an organizational and interorganizational scale.

Transformation of work and organizations associated with large-scale information and communication technologies (ICTs) is relevant to both the public and private sectors. This paper focuses on an LMIC that is pursuing ICT-enabled transformation of the public sector for socioeconomic change. Such initiatives involve computerization on a massive scale, facilitating centralized gathering of large volumes of highly granular data about individuals. Since 2008 the Indian Ministry of Health has enabled more than 200,000 health facilities to report data such as all names of pregnant women and children born in the country. This highly granular data about individual citizens was seldom collected before, even in nondigital formats. Massive digitization of the health information is networked and linked with other initiatives, such as the initiative to provide universal IDs for all Indian citizens based on biometrics, and also linking up with health insurance.

Such interconnected, large-scale, complex ICT solutions have been problematic in Western contexts. These are not merely technological interventions but also involve large-scale organizational transformations. Success requires a better understanding of what these transformations entail at the level of work, individuals, and organizations, but this is often missing from e-government and the ICT for Development (ICT4D) literature. E-government studies focus mainly
on the “supply side” of provision and performance of ICT systems (Bhatnagar and Singh 2010) while ignoring the demand side of use and work. An exception is Contini and Lanzara’s (2008) case studies from European e-government initiatives that describe how institutional and technological components are assembled and “tuned” to work together. The effort required to make such initiatives work has been severely underestimated, with “only sparse knowledge [...] available on the processes by which infrastructures are assembled” (Contini and Lanzara 2008, p. 2). This problem is magnified in the context of LMICs. Research in ICT4D focuses mainly on consequences of technology, not on work specifically; even the IFIP 9.4 working group on the social implications of computers in developing countries concentrates mainly on how ICTs contribute to development (Walsham and Sahay 2006, Gallivan and Tao 2013), not on the work or organizational interactions required to accomplish this.

This paper addresses this through an empirical study from the healthcare sector of an Indian state (called NSTATE). It describes an action research project involving a free and open-source hospital information system (here called HospIS) developed for more than 20 public district and subdistrict hospitals. District hospitals are where patients from rural areas first seek specialist services, and where outpatient department (OPD) doctors might see hundreds of patients in a day, with just a few minutes to converse, make a diagnosis, reassure the patient of their wellness, and prescribe medicines and diagnostic tests. Doctors rely largely on intuition and experience, and such knowledge being tacit makes it difficult to standardize and inscribe into software code. Most existing information processes are manual. Inpatient departments might have paper-based medical charts and archives, but work in OPDs is usually carried out without any support from historical patient information. Electronic patient record (EPR) systems are virtually nonexistent and difficult to introduce because district hospitals often have unreliable access to power, transportation, and communication infrastructure. They might lack diagnostic and therapeutic technologies, making it problematic and even unwise to try and emulate Western approaches. Novel solutions are called for, requiring appropriate hybrids of manual and automated work processes, building local capacity and new procedures and organizational structures.

The plan to introduce HospIS was motivated by NSTATE’s desire to improve care quality and strengthen continuity of care and efficiency of health service operations through reengineering work processes. Digitizing core information at the patient level and aggregating it to facility-based monthly statistics would allow linking of data across health facilities to develop comparisons of health indicators and performance metrics across facilities and help inform resource allocation decisions. The project has been successful, which allows learning about the process of design, development, implementation, and scaling of the system and its relation with work.

The paper discusses how HospIS introduction changed work tasks, met demands for new competencies, and effected transformations. The next section provides a theoretical perspective, §3 presents study details, and §4 presents the story of HospIS and associated transformations. Our analysis in §§5 and 6 discusses the implications of the study.

2. Information, Technology, and Work

The information systems field has a unique vantage point for understanding relationships among information, technology, and changes in work. The implementation of technology is a transformative process of mutual adaptation between technology and organization (Leonard-Barton 1988). “Emergent” perspectives (Robey and Boudreau 1999) are more nuanced than either technological or organizational imperative perspectives (Markus and Robey 1988), emphasizing a reciprocal rather than a one-directional relationship between technology and organization. The situated and context-dependent processes of transformation were discussed in the 1996 *Information Systems Research* (ISR) special issue on “Information Technology and Organizational Transformation” (Yates and van Maanen 1996, p. 1). Orlikowski (1996) identified a position between deliberate change, emergent change, and unanticipated outcomes by examining practice-based, situated change that consisted of appropriation, experimentation, adaptations, and improvisations in use. Robey and Sahay (1996) emphasized the contextual shaping of organizational learning, studying two implementation processes of the same technology with different outcomes. Star and Ruhleder (1996) discussed the trans-contextual nature of transformation associated with distributed, networked, collaborative systems linking multiple contexts, user groups, and use areas. A notable IS tradition of rich qualitative empirical studies offers detailed, nonnaïve accounts of reconfigurations of work, identities, organizational values and goals, and the technology itself. This paper is in that spirit.

2.1. Automating and Informating

Shoshana Zuboff’s (1988) landmark study was an in-depth examination of how people experienced transformation of work and organizations, building on concepts of “automating” and “informating.” In automation, workers do not interact directly with physical processes, but with representations of these processes. Through panel meters in a control room, information becomes visible, knowable, and
share (Zuboff 1988, p. 9). Through novel intellectual skills for interpreting and acting on information that becomes visible through automation, the potential for “informating” enables the organization to unleash new, transformative opportunities. Zuboff’s study, before personal computers and networking became prominent, focuses on automation of production processes and office work. An important exception to this is Global Bank Brazil’s effort to create an organization-wide, integrated database “to textualize the work of an entire organization” as opposed to just “textualizing the work of the office” (Zuboff 1988, p. 158). This foresaw an era where large-scale, interconnected systems of up-to-date information were expected to enable novel analyses, create new value-added information products, and better predict the future. The potential envisioned by Zuboff may be realized, but the nature of informating has remained underresearched. Lanzara’s (2008) and Kallinikos’ (2008) studies of ICTs in the legal domain are tied closer to automating than informating, focused on functional simplification and closure (Kallinikos 2005) through standardization, reduction, and simplification of institutional codes. This downplays the intimate and reciprocal relationship between simplification and enhancement. Standardization, reduction, and simplification entails enhancement of information’s potential (Scott 1988), and reduction of richness or particularity accompanies increased reach or universality (Latour 1999). The real potential and challenge of informating is associated with large-scale, interconnected systems. We examine how informating is related to processes of infrastructuring.

2.2. Work in the Context of Infrastructuring

Work is comprised of single tasks connected sequentially into task chains. Interdependencies relate task chains to each other. “New technologies first alter tasks and skills and… these changes create, in turn, opportunities and pressures for modifying organizational structures” (Barley 1990, p. 63). Work is goal directed; worker discretion and autonomy (or lack thereof) and improvisation are crucial in any working system (Gasser 1986, Suchman 1987). Worker skills, competencies, capabilities, and whether and how these are facilitated and supported by the organization, must be included in the analysis.

Some information infrastructure studies emphasize work, foregrounding the significance of users as designers and emphasizing ongoing “in-situ” design and redesign as the infrastructure evolves (Hanseth and Lundberg 2001, Pipek and Wulf 2009). Star and Ruhleder (1996) emphasize the intimacy of information infrastructure’s relation to practice: “infrastructures are something that emerges for people in practice, connected to activities and structures” (p. 112), whereas its use is “learned as part of membership” and it “links with conventions of practice” (p. 113). They argue that we should ask not “what is an infrastructure?” but “when is an infrastructure?” They advocate a relational and processual view on information infrastructures to capture interventions, actions, and transformations in designing and developing infrastructures. The verb “to infrastructure” has been used (Star and Bowker 2002), and Pipek and Wulf employ the notion of “infrastructuring” for “all activities that contribute to a successful establishment of usages” in the context of a groupware infrastructure (Pipek and Wulf 2009, p. 450). Pervasive challenges of infrastructuring include balancing between (local) heterogeneity and (global) standardization (Star and Ruhleder 1996, Rolland and Monteiro 2002, Winthereik and Víkkelso 2005), establishing metadata standards (Karasti et al. 2006), creating new knowledge representations (Ribes and Bowker 2009), and dealing with multiple temporal scales simultaneously, such as project time and infrastructure time (Ribes and Finholt 2009, Karasti et al. 2010).

These insights help us to understand “the work of infrastructuring.” We also examine information infrastructure impacts on existing work and organizations, referred to as “infrastructuring of work.” This is a transformation of organizations and practices that Lanzara (2008) and Kallinikos (2008) denote as functional simplification. It is often a prerequisite for new technology to work. Víkkelso (2007, p. 270) also points to “the groundwork that makes possible the diffusion and implementation of this new logic of governance,” building on Power’s (1994) analysis of the process through which organizations are made “auditable” by being restructured, and where new categorizations, routines, and tools are introduced to enable more effective monitoring.

The infrastructuring of work concerns how work is transformed so the new technology can function. Transformations are not unidirectional and linear, but an ongoing process where one cycle of change becomes the starting point for the next. Information infrastructures provide an “all-encompassing solution and an omnipresent problem, indispensable yet unsatisfactory, always already there, yet always an unfinished work in progress” (Edwards et al. 2009, p. 365). They are recursive, messy, and unfinished. Ongoing work is required to get an infrastructure to do what it is supposed to do but is “permanently unable to accomplish” (Jensen and Winthereik 2013, p. 156). Star and Ruhleder’s (1996) “infrastructural trans-contextual syndrome” (p. 127) refers to the interdependencies, couplings, and connections that an information infrastructure introduces when bringing together multiple sites, contexts, and activities over time. Information infrastructures exhibit multiplicity,
ambiguity, and potential for conflict that can only be resolved through ongoing negotiation processes. This paper examines the nature of and interrelation between work of infrastructuring and infrastructuring of work and how this evolves over time.

3. Research Approach
This study uses action research focused on “networks of action” (Braa et al. 2004), creating links between different units engaging in similar development efforts. Our case focuses on building software, capacity, infrastructure, and approaches in one hospital in expectation that these would spread to other facilities through an ongoing process of standardization. We describe the research site and the actors involved, as well as the design and conduct of the research and the specifics of data collection and analysis.

3.1. Setting the Stage: Research Site, Timeline, and Actors Involved
The setting is a northern Indian state that has relatively good public health indicators and a state government actively promoting stronger health systems through the use of ICTs. NSTATE is divided into 12 districts, with hilly terrain and a relatively sparse and widely dispersed population that relies largely on the public health system for care. There are strong political incentives for the government to strengthen and modernize the public health system.

NSTATE contracted with an Indian NGO (called INGO) to design, develop, and implement a hospital system we call HospIS. NSTATE and INGO have been collaborating since 2008, when the central government started reforming the health management information systems (HMIS) that produces aggregate statistics. INGO supported NSTATE’s development of an open-source software project to implement the District Health Information Software (DHIS2) chosen by NSTATE for HMIS. A 2010 tripartite Memorandum of Understanding (MOU) was signed between NSTATE, INGO, and a national health resource center to create an “e-health architecture” and design, develop, and implement HospIS. The MOU specified that the project would start with one hospital in the capital city and spread to the other 19 hospitals. The system was working in 12 months, and began to expand to other hospitals in a phased-in manner. The project is now in its fourth year and the system is up and running in the 20 planned hospitals. Future expansion is planned to two medical colleges and other community health centers, and HospIS has been adopted by other Indian states and countries.

Two of the authors are Indian and are integral members of the INGO team: one is a project coordinator of the NSTATE project and is directly responsible for operational aspects, and another played an advisory role in the project. Two are part of a global network called the Health Information Systems Programme (HISP): one is a mentor and advisor to INGO on issues of software, hardware, and intellectual property in the initial stages of HospIS development, the other is following but is not directly involved in the project. Insider and outsider perspectives were combined to create insights and enhance the trustworthiness of research results (Langley and Abdallah 2011).

3.2. Research Approach: Action Research Involving a Multilevel and Longitudinal Design
The project was to design, develop, implement, and scale HospIS across hospitals in NSTATE. The research approach was to balance and harmonize action and research components. Actions included negotiations and contract work, software development, implementation and capacity building, and managing the information infrastructure. Negotiations included defining a set of 10 core modules for HospIS using an existing open-source platform (OpenMRS) that offered basic functionality for a patient record repository, but no other hospital-related functionality. Additional functionalities had to be developed. HospIS included 10 core modules, reports, and a module that coordinated the others. Building it involved analyzing requirements, building prototypes, obtaining feedback, revising, managing software repositories, engaging the OpenMRS global community, troubleshooting, reporting on project progress, and other tasks. Such actions provided insights on building an information infrastructure, such as the tensions and contradictions in the ways that global and local processes feed into each other, and formal capacity-building processes are required to create manuals, protocols, troubleshooting guides, and other resources. These resources were required for INGO’s support actions that ranged from selecting technology (e.g., dot matrix versus laser printers), sustaintment (e.g., changing cartridge use for dot matrix printers), creating network design for the LAN, helping in the procurement of hardware, and generally “making things work.” By studying novel and routine demands, insights emerged regarding what information infrastructures require and how those requirements can be met.

The research covered multiple levels, from global through national, from state to particular hospitals and patients. INGO worked with the state to define the architecture of the system and resource requirements, obtain resources from the district authorities, and make the system work. They negotiated for new versions of the code released by the global OpenMRS community. INGO also worked with doctors, nurses, technicians, and hospital administrators to
understand requirements and get feedback on the system being developed, including implications for everyday work. The continuation project has enabled research into HospIS design and development from discussion and negotiation to full-blown product use in 20 hospitals (and more) in the state. Frequent visits to project sites helped with understanding of expectations and fears of actors, and how these evolved and changed, providing insights on process dynamics and interventions when required. Four years of engagements among the INGO team, hospital staff, and the state team identified issues for authorities and solutions where possible. This provided assistance for action.

3.3. Data Collection
Ongoing data collection used formal and informal methods, including discussions with users, hardware and network vendors, and state authorities. These generated knowledge of needs and requirements, clarifications on issues, review of progress, etc. Capacity building processes revealed users’ opinions of the system, requests for additional functionality and features, and other insights. INGO recorded requests and suggestions from users in logs and suggestion books. Meetings and presentations on the project provided INGO with comments and useful data to guide the evolution of the information infrastructure. Written documentation was maintained for requirements analysis of each module, flow of patients and information from one department to the other, progress reports, protocols for use of different modules, training materials, state websites, technical notes on models of knowledge transfer, signage in hospitals to inform patients of revised processes, etc. A project management system called Redmine was used to archive project documentation, including all reports, presentations, bug fix requests, bug fixes, and the like. Thousands of email messages were exchanged among team members and between team members, hospital, and state authorities. These were saved and served as a means of data collection. Traditional data collection methods for IS research, such as interviews and observations, were used when appropriate, but data collection was mainly through means for actors to contribute to the project. The project story told here is constructed using these project data.

3.4. Data Analysis
Practical knowledge to implement the project generated theoretical knowledge for research papers. Periodic project discussions focused on progress, challenges faced, and inferences regarding insights and knowledge. For example, while working on the interoperability module to link HospIS data to the state’s DHIS2 system, interesting insights emerged about the aggregation logic of chronic and nonchronic cases. A hypertension patient making multiple visits to the OPD would be counted once for a monthly report, whereas a diarrhea patient making multiple visits would be counted for each visit. The hospital epidemiologist was unable to follow the logic of this difference in the manual system, but wanted the HospIS system to conform to the same logic to get the correct “burden of disease” for the hospital.

Theoretical issues of standardization and participatory design were related to changes in work. These came out at colocated meetings of our globally distributed author team. Colocation allowed us to do comprehensive joint analysis, test conceptual ideas, and compare experiences summed up in analytic memos that were distributed and commented on. Topical discussions were conducted in Skype meetings of one-two hours, paper drafts were circulated, and authors’ interpretations were communicated through writing, questioning, and commenting on each other’s texts. This process facilitated analysis and resulted in practical engagement with reality in a multifaceted, multilevel, and longitudinal way. Insights biased in the minds of given authors were challenged by others with greater distance from the action. This helped maintain objectivity in the work.

4. Developing and Implementing HospIS

Intentional, intervening actions led to transformation of other people’s work (Huy and Mintzberg 2003). The transformation of work tasks, task sequences, and organizational structures created the need for additional or new types of work. We call this interplay the “work of infrastructuring” and the “infrastructuring of work.”

4.1. Changes in Work

The INGO team conducted requirements analysis, iterative rounds of participatory design of system features and redesigned work processes, and software development. They took 12 months to build the core modules described in the MOU. Following implementation, they supported users, solved emerging issues, and worked with the state to spread the system to other hospitals. The state prioritized modules to offer “low hanging fruits.” The patient registration and billing modules were the first to go live in the hospital. We start with how work changed for registration and billing clerks, and other groups like laboratory technicians.

4.1.1. Registration. Registration clerks, employees of a local company contracted to do data entry work, sit at two registration desks in a room facing the central hospital yard. Previously, HospIS clerks
would enter an outpatient’s name, age, and relevant OPD information in a rudimentary, stand-alone computer system. There was no compulsory registration, and patients would approach the laboratory, radiology, or plaster room at their own discretion. First-time patients who wished to meet with an OPD doctor had to register to get an “OPD slip.” Revisit patients would reuse a slip from a previous meeting, not bothering to register. The OPDs were overcrowded and the queues unruly. The hospital could not analyze its existing patient load, demographic profiles, or referral information.

HospIS changed the work of the registration clerks through compulsory registration of new and old patients. Clerks would screen patients and allocate them to appropriate queues. The process was later redefined so that clerks directed most patients to the general OPD, which screened the patients and referred to specialist OPDs only if required. Clerks would still direct pregnant women and patients with tooth ailments or fractures directly to the relevant OPDs. During registration, patient names were added to queues for appropriate OPDs that would call patients in sequence as indicated by the system. This reduced waiting time, but increased work for the registration clerks who had to gather additional information from patients and enter more data than before.

This increase emerged from requirements elicitation where actors presented their wishes for information. Hospital management wanted to capture patient demographics and categories of patient treatment (free, partially free, paid, etc.). Public health officials in the district and state wanted to capture patient addresses and referrals, to see patient flow patterns in the catchment population, and link in-referral loads with reasons for referral. State authorities wanted to use HospIS as a tool to standardize patient registration across the state and ensure compatibility with national initiatives such as the Universal Identification System. Patient registration information was captured under four subheadings:

- Patient demographics (name, age, gender, address, phone number, next-of-kin).
- Patient category (health insurance type with number, below poverty line beneficiary, state government employee, central government employee, physically challenged).
- Referral information: referred from type of facility (primary health center, health post, community health center) and reason for referral (investigation, surgery, clinician, tuberculosis).
- Instructions on which OPD room to visit.

Upon registration, each patient was given a unique identifier by the system. The registration clerk would ask if this was their first visit or a revisit. In case of revisit, the system was searched by identifier or name.

The hospital had no IT support structure to manage the day-to-day running of the technical infrastructure. There was no IT department and nobody to train. Some data entry clerks showed eagerness to learn new IT skills. They seldom had the required educational background, but INGO trained them to offer basic support (clearing paper jams in printers, checking the LAN, restarting the server after a power outage, doing data backup). This was cheaper for the hospital, and for the staff constituted an expansion of personal skills that could make them more attractive as employees. This initial, practical remedy is now being replaced with more formalized support structures. Revision and updating of information security, records management policies, and disaster recovery procedures created new demands, and INGO worked with hospital management to create a set of guidelines based on a simplified ISO27002 framework.

4.1.2. Billing. The billing counter is operated by clerks from the same company as the registration clerks, and is located next to the registration desks. Billing used to be conducted at distributed examination rooms and labs where patients had to pay before receiving services. If an OPD doctor requested a lab test, the patient had to go to the billing counter to pay, whereupon the clerk ordered the test and assigned the patient’s name to the queue of the lab. With HospIS, the billing function was centralized and linked to the patient queues. The new link was bidirectional: an unavailable lab service could be registered in HospIS. Then the billing staff would not charge the patient, but ask them to return another day.

This represented a significant change in work. It increased the flow of information between various services, improving logistics such as fixing equipment or ordering supplies. Centralization of billing offered management a better overview of income and cash flows. Billing clerks would generate “cash collection reports” at the end of the day and submit them to the accounts department along with the cash collected and send copies to the hospital manager. A hospital manager who had noticed a drop in cash collection for a week that had a normal OPD load contacted INGO, which recognized the possibility of pilferage by the billing clerk even though cancellations could happen for legitimate reasons. Collecting voided or canceled bills in the daily cash collection report allowed tracking, and the report was changed to include this. A change in billing procedures to increase visibility of cash flows caused effects not originally foreseen.

4.1.3. Laboratory. HospIS changed the work of technicians in laboratories and plaster rooms. Previously these technicians maintained 10 registers: a cash book for payment by each patient, a poor patient book for those given free services, five patient result registers (one each for hematology, biochemistry, serology,
urine, and cytology), a reagent register to maintain stock of reagents used, and two stock registers to maintain stock of things like test tubes, vials, gloves, stationery, etc. HospIS shifted these tasks to others, and established centralized sample collection and report distribution that allowed the lab to increase opening time from four to six hours for sample collection.

This was an improvement for patients. Previously, doctors would write investigation orders on an OPD slip, the patient would go to “room number 31” to have a clerk fill the slip with information (patient details, test names, amount to be collected). The patient would take the slip to the lab, the lab technician would collect the payment and collect a sample, and the sample number and test results were written on the slip that was returned to the patient, who would take the slip to the doctor. Multiple sub-labs, with each maintaining several registry books and patient slips made the process complicated. A test for fasting blood sugar and hemoglobin required a blood sample to be analyzed in two sections (biochemistry and hematology), resulting in two slips for the patient. HospIS allowed a central location for sample collection that distributed the samples to the sections, collected results, and produced a consolidated result sheet to give to patients. The trip to room 31 was eliminated.

Building the laboratory module resulted in additional functionality. Normal ranges were identified for different tests, and test results were written in reference to these ranges. Patients received results in printed and legible form, on one page, and in relation to a reference range. These changes helped patients who had to take remedial action on test results. The ranges became part of HospIS and were subsequently used by other hospitals, leading to bottom-up standardization. Digitization relieved the labs of manual, tedious updating, and ensured better resource management with fewer stock-out occurrences.

4.1.4. Nursing in In-Patient Wards. HospIS also affected the dispensing of drugs in the in-patient department, where nurses manage patients and administer drugs as advised by doctors. The nurses asked the INGO team for a change to account for drugs that were not given to a particular patient, but were lost on the floor, soiled, removed by doctors, given to poor patients, etc. The simple “issued to account” change made by INGO caused hospital managers to object that this could result in malpractice, so the issued to account functionality received an additional comment field explaining the reason for use. This example shows that HospIS could reduce workers’ discretion and autonomy, but managerial logics could also be contested and modified based on work-based logics. However, this was not uniform across the hierarchy. Doctors might remove the drugs without bothering about documentation, leaving the nurses to explain.

4.1.5. Clinicians. OPD doctors sometimes encounter high workload, seeing hundreds of patients each day. Failure to document OPD encounters was common. OPD doctors might not commit to a diagnosis, but only write the symptoms and prescriptions on the OPD slip. Management and the INGO team built HospIS to require doctors to document encounters correctly, make diagnoses, and note required tests and examinations. To facilitate this, the system offered a drop-down list of the most common diagnoses for the respective OPD, gathered through a participatory process. Over time, HospIS accumulated information and offered doctors the opportunity to consult histories of recurring patients. Hospital management would know more about OPD activity. Nevertheless, doctors still did not enter all OPD encounters into the system, maintaining longitudinal records only for chronic and recurring patients (e.g., tuberculosis or diabetes).

Other experiences produced different outcomes. Reports from radiology used to be handwritten in free text on hospital letterhead. Staff objected to typing this text into the computer because of limited typing speed and high patient load. They suggested standardizing on predefined radiology categories for each type of investigation. Discussions with an expert from the local medical college and other radiologists generated lists of radiology investigations done in the hospital, parameters for observation, and result options. Forms for 36 specific investigations were created, and users could define new forms if the hospital hired new staff or purchased new equipment. Designing this common report stimulated interorganizational peer consultation and joint learning, and formed the basis for analyses of laboratory and radiology work. There was no conflict between managerial and professional agendas and usages of the system, contrary to what happened with OPD documentation.

4.2. Scaling HospIS Beyond the Hospital

Expanding HospIS started in early 2011 with requirement analyses to assess customization for each hospital. Two or three INGO team members would be in the hospital for a week to study workflows, collect forms and artifacts, and create a roadmap for system customizers to tailor HospIS to the hospital. They designed the local area network and identified needs for hardware and physical placement of that hardware in the hospital. State and hospital administrators handled third-party contracting for the LAN and hardware, following INGO’s specifications. When networks and hardware were ready the INGO team would install the server, test the LAN, provide training to users, and ensure that basic processes were up...
and running. Some remote hospitals had to be made as self-sufficient as possible because external support was too far away (up to 18 hours travel by road from the capital city where the INGO team was based).

About 80 standard reports created by different departments in the first hospital, plus routine reports sent monthly to state and national levels, became part of the core system taken to other hospitals. NSTATE had data come to a common repository for comparison of key hospital management indicators across facilities. The data warehouse receiving hospital reports used the state’s centralized information portal and statewide virtual private network for secure connectivity. Novel uses of the shared repository emerged. Data from blood banks come to the repository every night, allowing a daily stock report of stock positions by blood group and content in each blood bank. This allowed hospitals to identify where to source blood units when needed. The shared repository also enabled a weekly drug expiry report reporting each hospital’s stock of soon-to-expire drugs, helping hospitals reduce wastage.

4.3. Sustaining Transformation

Beyond the Hospital

Expansion required redesign of the network and improved maintenance of computers, printers, and other peripherals. NSTATE negotiated third-party contracts to be managed by each hospital’s system administrator, but hospital recruitment restrictions mean it will be a while before INGO is no longer providing support. The local IT firm INGO recommended for data entry received a contract to provide hospital support, including training. This has worked initially, but is not optimal for large, distributed infrastructures. An alternative solution is now under way, including recruitment of workers to staff state and district “IT cells.” These cells will offer ongoing support and refresher training in computer literacy and HospIS.

4.4. “Informating” the Hospital and the State

Installing HospIS in district hospitals facilitates data collection for a centralized repository that enables analysis at the hospital and state levels. Consolidation of patient registration data now being collected will allow state health authorities to examine referrals (where patients come from, for what service, demographic profiles), disease profiles (diagnoses disaggregated by age and gender), hospital management (billing, stocks, patient loads, bed utilization, etc.), and epidemiology (disease incidence and prevalence, patterns in the spread of diseases). Such data can be used to identify weakly performing units and formulate plans to strengthen performance. They can be used to construct disease and mortality profiles, a big gap in health information today. They can facilitate improvements in social coverage and insurance. Hospital managers can strengthen administrative processes, improve resource optimization, and conduct interhospital comparisons of performance, resource utilization, and disease burdens. Epidemiologists can strengthen research and analysis at the state level and improve understanding of disease cause and spread. These potentials might take time to achieve, but such improvements are possible.

Informating builds on increased volume, scope, and richness of data collected, as well as linking data across the state. It requires novel information management skills and routines in the state and hospitals. For instance, the concept dictionary in HospIS needs to be maintained to reflect practices such as new tests and procedures introduced in individual hospitals and ensure coherence of concepts across user communities. This requires new organizational routines and responsibility structures not initially envisioned.

5. Analysis

Zuboff’s concepts of automating and informating were focused on stand-alone systems. In this section we extend them to large-scale health information infrastructures.

5.1. The Relation Between Automating and Informating

Zuboff’s account suggests automating and informating occur sequentially, but our case shows they can occur in an intertwined way. The functional simplification associated with automating seen in the introduction of standardized structures for radiology and lab reports brought standardization of work practices and tools across the sites. This allowed for informating by enhancing the availability and quality of data and allowing analyses of radiology and laboratory work. The standardization process helped to informate through consultations with radiologists from different organizations, and required the HospIS team to engage with global standards. In both cases new processes of interorganizational peer consultation and joint learning evolved.

Zuboff saw informating as a potential consequence of automating, but automating and informating do not necessarily occur together. Increased data collection is not just a by-product of automating work processes, but can be a separate, deliberately intended process. NSTATE desired to informate its health services by collecting more data at finer granularity, linked with global codes, accumulated over time, and available to more stakeholders. Clerks had additional work, laboratory technicians and radiologists
saw simplification and enhancement, and OPD doctors resisted system-imposed increases in registration data through "selective informating" when they chose to maintain the historical medical record only for patients with chronic diseases like tuberculosis and diabetes. Doctors interested in clinical care might have different goals for informating than workers responsible for administrative tasks.

5.2. Automating and Informating in a Networked Context

Another source of change was the networked character of HospIS at both the organizational level and as a statewide information infrastructure. As information about work became visible in other locations, information and work-related linkages and dependencies required organizational redesign. Patient lists were displayed to doctors as queues on a screen, helping patients to avoid crowding doctors' offices while waiting their turn. Billing clerks could see unavailable laboratory services, improving the patient experience. Fragmented and departmentally independent processes for revenue collection were centralized to the billing counter, freeing labs and other units from collecting their own fees and maintaining recording and reporting systems. Management could analyze revenue and collection trends, simplify monthly reporting, and better control cash flow. Tasks were transformed as links were created. Departments experienced a redistribution of power and increased transparency regarding revenue collection, lab efficiency, and so on.

Links were formed across hospitals, and between hospitals and external actors. The outsourcing agency hired to carry out data entry in time enhanced IT support for the internal hospital staff, while showing the state that this model was inadequate. To provide greater sustainability the state defined job profiles and established IT cells at hospital, district, and state levels. Terms of reference were defined and analysis was done to determine recruitment profiles for IT cells to keep systems functional and provide the knowledge needed. More objective and performance-oriented expectations emerged, unusual for hospitals in the Indian public sector.

What distinguishes “infrastructuring” from mere computerization or digitization of organizational information systems is the networked and trans-contextual character of infrastructures that can bring further changes in work. This study showed that local computerization combined with a networked, statewide information infrastructure creates potential for reorganizing relations between hospitals. Thus far this change has been rudimentary, allowing hospital staff to access other hospitals’ stock registers for sharing supplies. But there is promise for more direct, physical automating (delegating tasks such as inventory control, queue management, report generation to the system) to become accompanied by networked automating, in which informating processes and networked informating processes may emerge.

5.3. Recursive Relation Between Infrastructuring of Work and Work of Infrastructuring

Infrastructuring processes can build shared, nonlocal solutions for the long term. This requires sustainability, maintainability, and flexibility to accommodate future changes. These processes are recursive: a pattern of infrastructuring, transformation of work, more infrastructuring, and so on. The work of infrastructuring takes place over time. It goes beyond systems development and includes physical infrastructure, design, development and implementation of software, maintenance of infrastructure hardware and networks, building capacity, establishing metadata governance, institutionalizing support capacity, and similar tasks.

The infrastructuring of work occurs when users draw on available infrastructure for specific work processes to exploit commonalities and links beyond the local work site. It happens when users exploit logistic and information links between task sequences in the organization to comply with standards and rules, or enable novel possibilities. In the HospIS case transformation occurred when links were created among users, departments, and information flows within hospitals. These links extended across and between hospitals at the state and national levels. They enabled interrelated work practices, knowledge sharing, and learning across the network. Enhancements in data flows and links facilitated coordination of work and novel analysis. More integration is possible as more data are collected, of different types and granularities, across geographies, and over time. Creating networks of work, information, and infrastructure can bring enhancements and simplifications in work. These can trigger more infrastructuring, especially given that infrastructures do not have start and end dates, and are always in the making.

The work of infrastructuring involves computers processing new forms of information, carrying out infrastructure- and information-related tasks that did not exist before. It involves working at different speeds and volumes than possible with manual systems, reflecting enhancement of responsibilities, skills, and knowledge. It requires work that is interdependent with and in some cases independent of others, recursive and ongoing, with no finite end dates. Users and implementers experience enhancements and simplifications, and demand more infrastructuring, triggering more impacts. In the initial stages of HospIS the priority was making the system work, dealing
with resource constraints, and meeting demands of administrators and politicians. As the INGO team learned to manage the infrastructure and take it to other facilities, new possibilities emerged.

6. Discussion

The transformation of work and organizations around ICT is an ongoing process rather than a one-time event (Goh et al. 2011). The introduction of the new information infrastructure of HospIS transformed work and triggered demand for novel work. The HospIS case foregrounds the way this process occurred, shaped by infrastructural issues that go beyond the organization in question. Rather than treat the organization as a unit of analysis, we examined the interplay between work of infrastructuring and infrastructuring of work that occurred in the participating organizations and in the state’s healthcare system as a whole. The effects of the HospIS ICT were at the network level as well as within each organization. As organizations become increasingly networked, this is relevant for the wider IS field. However, this networking cannot be taken for granted in LMICs that suffer from chronic power shortages and resource constraints. LMICs require provisions of enabling conditions that are a given in resource-rich settings.

Information infrastructure studies involving multiple levels, scales, and timeframes show the need to bridge between global/local, large/small, and long-term/short-term (Edwards et al. 2009, Karasti et al. 2010, Ribes and Finholt 2009). They illustrate how work transformations occur at multiple levels and scales. Our study takes place in a non-Western context, a public health setting in a developing country facing high patient loads, limited resources, little experience with IT systems, a near absence of informational and care standards, limited existing regulation, poor conditions of network connectivity, and unreliable power supply. Simplicity, feasibility, sustainability, and robustness were central.

Infrastructure changes over time are realized gradually. INGO initially wanted to make HospIS work within financial constraints, managing expectation’s expectations. However, the importance of long-term sustainability was realized gradually in demands for new skills, actions, and resources as the infrastructure grew. Expanding HospIS to other hospitals triggered reorganization of work in INGO, who had to “learn to see” and deal with the challenges that emerged. Preparing to deal with future issues not yet visible remains a challenge for INGO.

INGO learned modes of work that indicate how public sector organizations in LMICs might approach building information infrastructure. Action research helped make these clear. Providers of high-end technology solutions often have limited understanding of work in context. Short-term, project-based objectives drive out long-range considerations. The INGO team’s historical relationship with NSTATE provided a foundation of trust that enabled mutual learning and organizational transformation. The free and open-source software base from OpenMRS facilitated development of local ownership and governance. Interactions between INGO and NSTATE and the desire to learn mutually helped the transformation to “in-situ design work” (Pipek and Wulf 2009) in which users and developers jointly participate to resolve problems. The infrastructural background work that produces insights and resolves emerging issues required ongoing engagement among designers and implementers in the hospitals and at the state level. This facilitated local and professional ownership related to use, exploitation, maintenance, and governance of the system.

7. Concluding Remarks

Building a statewide hospital information infrastructure in an Indian state allowed us to study changes in work and work relations. Establishing, introducing, and maintaining such an infrastructure offered insights for transformation of skills and capabilities, organizational processes, structures, and governance mechanisms. Seeing automating and informating in relation to infrastructure led us to identify the interrelated processes of the work of infrastructuring and the infrastructuring of work.

Our study is aimed at better understanding, planning, and managing the process of digitizing public sector institutions in LMICs. Establishing large-scale information infrastructures is context dependent, shaped by electoral processes, governance structures, telecom policies, funding, donor policies, and other factors. Although “frugal innovation” (achieving more with less) is necessary for LMICs, it could also be relevant to resource-rich Western contexts. The saying goes, “money cannot buy results.” Insights regarding digitization of public sector institutions are relevant to ongoing efforts, such as the World Health Organization’s initiative to introduce universal health coverage by establishing systems for health insurance and financial risk protection for every citizen. The United Nations Commission of Information Accountability seeks to track every mother and child to ensure appropriate care, and recommends digital systems for Civil Registration and Vital Statistics to register and track every vital event (e.g., birth and death). Civil registration reported by hospitals must then be linked to other agencies. Such large and interconnected systems are difficult to build and maintain, but the insights from NSTATE’s efforts can guide development.
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