MCIS 2008 Proceedings

Mediterranean Conference on Information Systems (MCIS)

10-2008

MULTIPLE LOGICS AT WORK IN INFORMATION INFRASTRUCTURE IN USE: A CASE STUDY ON HEART TRANSPLANTATION

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Abstract

This paper investigates the information practices of different professionals in a distributed and interdisciplinary work process. Specifically, it looks at how a collection of information artefacts, both electronic and paper based, is used in the process. To conceptualize heterogeneous and collective artefacts in use, this paper draws on the literature on information infrastructures and on recent development in Actor-Network Theory. The empirical material presented comes from an interpretive case study on the heart transplant process in a large hospital in Norway. The paper discusses how the information infrastructure in use in this process works coherently according to multiple logics of information use. The findings are related to the nature of technology as complex object in use and their relevance is discussed in relation to change processes in hospitals.

Keywords: Information Infrastructure, Actor Network Theory, Health Care, Heart Transplant.

1 INTRODUCTION

Information infrastructures have been studied as complex objects that work in between communities of practice across localities (e.g. Bowker and Star, 1999). Other studies have shown how infrastructures work at different levels: both locally and globally (e.g. Rolland and Monteiro, 2002). Differently, Pollock et Al. consider the stretching of infrastructures from being locally developed to address the demand of context-independent use (Pollock et Al., 2007). Moreover infrastructures are of different type in that they can be more or less defined. For instance the above mentioned studies deal with information infrastructures that are well packaged and standardized. Most of the existing studies on information infrastructure share this common characteristic: they all focus on the centrality of a particular system, standard, or a confined set of them. That is, while conceptually infrastructures are defined as heterogeneous assemblages of different systems and standards (see for instance the definition of information infrastructure in Bowker and Star, 1999; and in Hanseth and Lyytinen, 2004), the empirical focus is often on a pivotal part of the infrastructure, be it a system, a confined collection of systems, a standard or a package of standards (see for instance the case studies in Ciborra et Al., 2000; Rolland, 2003;Hanseth et Al. 2006; Hanseth and Monteiro, 1996; Hanseth, Monteiro and Hatling, 1996; Bowker and Star, 1999). The implication is that the research is to a large degree shaped accordingly and its conceptual contributions directed towards understanding negotiations and dialectics supporting or questioning overall strategies of infrastructure development and stabilization.

But there are other types of infrastructures. In some cases information infrastructure are more difficult to identify as object to study than in other cases. The empirical material reported in this paper describes a process-oriented information infrastructure which is distributed and decentralized. It supports the heart transplant process in a large hospital in Oslo, Norway. The collection of interrelated information artefacts "gluing" together the heart transplant process and enabling the treatment of patients is not an easy object to define. There is no one major system and the EPR (Electronic Patient Record), which is usually consider "the" central hospital system, is one of many others. This decentered and distributed infrastructure is an occasion that challenges us to reflect about the nature of information infrastructures as complex object. And attending to the complexity of the object and to an appreciation of complexity, requires a shift in focus from issues of stability and alignment. Rather, in order to study this types of infrastructures, and on the basis of the analysis of my case study, I argue for the importance to pay more attention to how in situated practices infrastructures work in a decentered way by relying on multiple logics at work. In order to do so, theoretical resources are drawn from literature within Actor Network Theory related to issues of complexities and multiplicities and specifically the concept of modes of ordering is used. This literature and the selected concept are presented in the next section.

2 THEORETICAL LENS: MULTIPLICITY IN ACTOR-NETWORKS

In early ANT studies, technologies, and material artefacts in general, take part in the stabilization of networks. Technologies are studied either by looking at the inscriptions they carry (street bump, doors, key knobs), or by looking at how they came to be stabilized (or they fail to be stabilized) see for instance the case of Aramis in (Latour, 1996). In ANT and After studies (Law and Hassard, 1999) the focus shifts to more complex dynamics. Technologies become elusive objects with changing shapes and blurred boundaries.

For instance, Annemarie Mol and Marianne de Laet describe the Zimbabwe bush pump as a *fluid technology* to picture the instability which characterize it (de Laet and Mol, 2000). The boundaries of the pump are fluid (maybe it includes also the village community maintaining the pump), but also the mechanical components are fluid (pieces that are designed to be essential, can be replaced with other pieces at hand). Moreover, the definition of what "clean water" is changes: for instance the water of the pump can be contaminated but still considered clean because is anyway less contaminated than alternative water supplies. Thus there is no fixed structure of the technology, but it changes and adapt

when is installed and used locally. Another study which point at a similar understanding of technological systems is the analysis of the collision between two trains at Ladbroke Grove, outside London (Law, 2000c). Law discusses how the complex security system in place is inherently imperfect, but imperfection is unavoidable and necessary. It is not possible to specifically locate what went wrong, rather the security system works by different logics, building different set of relations at the same time: for instance a rule-breaking logic allows the system to function more effectively, and it co-exists with a logic of rigid application of rules. This non-coherence, or partial coherence is usually downplayed and considered as an error. It is not recognized as legitimate, but it is more robust than a single logic of tight control. Law's concern with non-coherence is elaborated further in Aircraft Stories (Law, 2002). Here he examines the (failed) attempt by the British government to build a military aircraft. An aircraft is a complex technology that lives at the intersection of different, partially overlapping, complex worlds. And it is also a not-singular object made of different versions, for instance can be talked of in term of technical details, like the shape of wings, or by analyzing how it performs (for instance its speed). But it has also a military role, and political attributes. Moreover all these versions interfere with each other in complex ways and somehow produce a coherence called the TSR2. In conclusion, in these analyses technologies are not in search of stabilization, or work because they are stabilized in a specific set of relations. Quite the opposite argument is put forward: technologies work because they are adaptable, because they change shape. And when they fail to work, there is no one network to blame, or one place in the network.

An interesting concept to open up the stability and unity of networks is that of modes of ordering (Law, 1994). Law argues that in actor-networks is possible to identify recurring patterns, called "modes of ordering", which are generated and reproduced as part of the ordering of human and non human relations (Law, 1994). "Ordering" is the process by which networks shape themselves. Modes of ordering are contingent and recursive, and they do not stand outside their performances: *"they do not drive (those) networks. They are not outside them. Rather, they are a way of talking of the patterns into which the latter shape themselves. (…) We should consider in practice how and how far ordering modes tell, perform and embody themselves in the networks of the social" (Law, 1994, page 83 and 124).* What a mode "orders" is heterogeneous and comprises social, material, discursive, practical elements. Moreover, there is never one ordering mode, they are multiple and may overlap, interfere, clash, create tensions and incompatibilities. Sometimes one mode becomes dominant and successful, but other more silent modes are always present. The concept of modes of ordering is used in the analysis to identify the strategies at work in the heart transplant process-oriented infrastructure in relation to information use.

3   RESEARCH METHODOLOGY

The research reported in this paper is based on an interpretive case study conducted in a large hospital in Oslo (called National Hospital) (Klein and Myers, 2001; Walsham, 1993; 1995). Data collection occurred over a period of four years (January 2002-June 2006) employing techniques as semi-structured interviews, observation of work practices, document analysis including paper based patient journals, paper forms, screen shots of systems, scientific publications. The obtained data have been analysed by organizing them on three levels: (i) the chronological sequence of events of the patient trajectory with a focus on the different work practices involved in the making information 'flow'; (ii) a description of the various information artefacts in use in the process in the three main departments of Cardiology, Thoracic Surgery and Immunology with a focus on the type of information collected and used in the different practices; (iii) the identification of four modes of ordering information in the process. This analytical concept works by making visible certain forms of coherences across the diverse practices.

4   CASE STUDY DESCRIPTION: HEART TRANSPLANT PROCESS

The practice of heart transplantation is based on the interrelated development of mainly three medical disciplines: cardiology, surgery and immunology. At the National Hospital, it is based on the

collaboration among the Department of Cardiology, the Department of Thoracic Surgery, and the Institute of Immunology (IMMI). Each of them in turn cooperates with other clinical and service departments, laboratories and institutions both within and outside the hospital. The heart transplant a process begins with the patient diagnosis of a serious cardiac condition and it ends after the transplant surgery with the follow up of visits and exams which continue for the rest of the patient's life. Specifically, it can be divided into four phases: (1) the evaluation period includes a series of specialized visits, examinations, analysis to assess the overall condition of a patient and to see if any other intervention is a valuable alternative ; (2) the waiting time is the period after the patient is accepted on the waiting list until the surgery takes place; (3) transplant surgery period includes the actual transplant and also the donation process; (4) follow up after transplantation consists of a post operative period in the hospital and the follow up of controls after the patient is discharged. In the process a large amount of information is produced and managed over a long period of time.

The information infrastructure for heart transplantation groups together different systems and artefacts, some are very specific and used only in single situations, other are shared documents or shared systems. Specifically, they can be categories into centralized, infra-departmental, infra-institutional and local artefacts. Centralized are those artefacts that are unique for the whole hospital like the patient journal and the forms it contains. Infra-departmental are those artefacts that are use to communicate in between department, like the order form for radiological examination which is filled in the Cardiology department and then sent to the Radiology department to order an examination. Artefacts that are infra-institutional are those that are used for communication between hospitals, or between the hospital and the Scandiatransplant organization. Local artefacts are those that are used within departments like the ward daily patient list for the department of Cardiology, or the operation waiting list for the department of Thoracic Surgery.

Figure 1 represents the process oriented information infrastructure of the heart transplant process. It shows as the process unfolds in time, the different main information artefacts used in the various stages. The infrastructure starts from the information produced during the evaluation process. Specifically on the left side of the figure (1) are listed all information sources that are used to take the decision of acceptance or not of a patient for transplantation (EROS is the laboratory information system for the Clinical Chemistry Department). If in the Heart Meeting (2) it is decided that the patient is accepted, a paper-form of acceptance is filled and sent to IMMI. Information of acceptance will then be registered in Nyrebase/HLA Lab (the main information systems used in IMMI) (3), and in the Scandiatransplant system (the system of the Scandiatransplant organization which manages the common waiting lists across Scandinavia) (4). From Nyrebase/HLA Lab the waiting list is printed on paper in several copies and sent to (5) the transplant coordinators in Cardiology, the transplant coordinators in Surgery and to the transplant thoracic surgeons. When a donation is available, information about the donor are communicated to the surgeon on duty (6) that will decide on the matching with the recipient. Afterward the transplant surgery takes place (7), and information about the surgery are registered into a number of systems and paper archives (Datacor is the information system used in the Thoracic Surgery Department) (8). In the period after the surgery and for the rest of the patients life information are collected periodically into the EPR and exams and laboratory results are also filed in the patient journal (9).
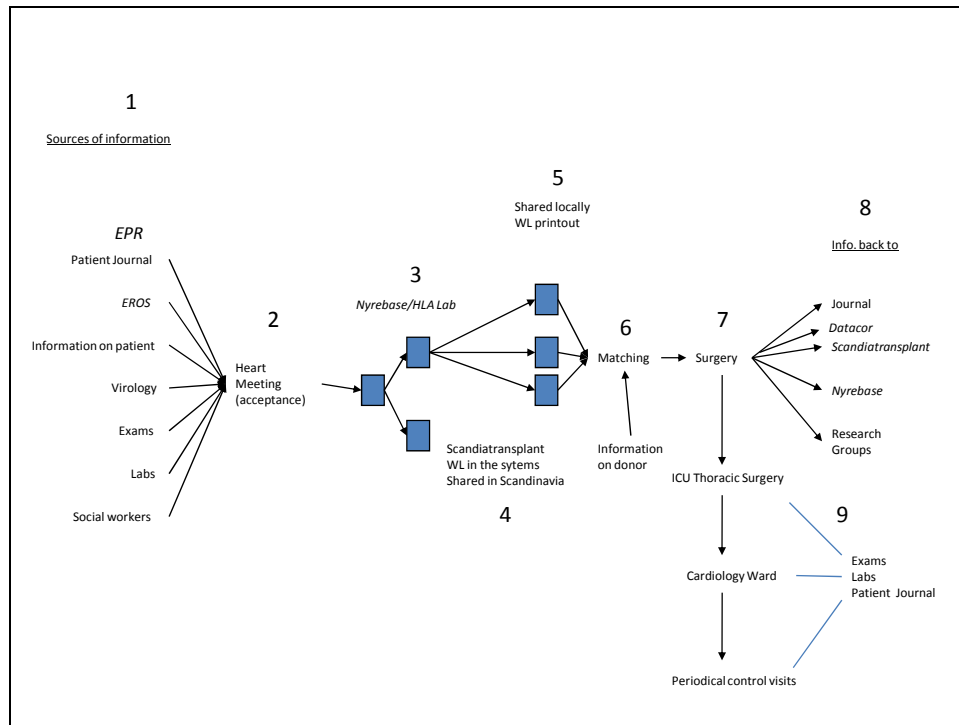
Figure 1. *The process oriented information infrastructure of heart transplantation at National Hospital.*

5 ANALYSIS: MODES OF ORDERING INFORMATION

In the analysis of the case I argue that processes of collecting, distributing and using information happen in different ways. There are multiple logics at work governing this network of information use enacted in the heart transplant process. These different ways can be identified and analyzed as modes of ordering information in use. In the following, I identify four modes of ordering and show how different ways of using information enacts logics (modes of ordering) which enact the collective differently. Each mode works by making singularities, that is, they produce a different representation of what heart transplantation is.

In making explicit different orderings in the work enacted by and in the collective of heart transplantation, I want to argue how what is perceived to be a "process of information flow" is actually going in several directions. Thus, I suggest that to conceptualize the use of information in terms of modes of ordering is a way to address aspects of the complexity inherent in making the process work. The modes that I have identified are: (i) the patient-centred ordering, (ii) the treatment-centred ordering, (iii) the procedural ordering, and (iv) the planning ordering. I present each mode by focusing on the singularity it produces and the artefacts involved.

5.1 Mode I: patient-centred ordering

In the patient-centred ordering information is produced and collected to make visible and manage the medical history of each patient, to see the singularity and specificities of each patient. This implies a concern for the chronological order of information to be able to assess what has been done, what are the results, what is currently happening, and what are the next steps within each single patient case.

Central artefacts in this mode are the checklist used by the coordinators in cardiology, the checklist used for the donation, the F1 form, the large paper forms used in the ICU in Thoracic Surgery, the paper-based patient record and the EPR. The checklist used by the coordinators and the nurses during the evaluation period helps to keep track of all exams and visits. This is a central artefact for

coordinating the work of the nurses and coordinators across their shifts, and during the days a patient is evaluated. A similar function is performed by the donation plan. This form starts to be filled when a donor hospital communicates that there is likely to be a donation and traces the trajectory of the donor in time. Other artefacts have more defined time frame of use. The F1 form used in the cardiology is designed to register data for a week, while the large forms used in the ICU are designed to register data by the half-hour for 24 hours a day. Thus in collecting information on single patients case, these artefacts vary in the time period they cover and respond to the need of the specific contexts of use.

The paper-based patient record and the EPR are the key artefacts in this mode as they are the repository of the medical history of each patient. This mode generates a temporality of events around each single patient. It works by organizing information in chronological sequence: this creates a timeline and allow data to be confronted against each other for each single patient. This mode is well represented by the paper based patient record and the EPR. And also HLA-Lab.

5.2   Mode II: treatment-centred ordering

In the treatment-centred ordering information is produced and collected to make visible and manage heart transplantation as a specific treatment. This implies a concern for the way information is ordered according to a specific categories of patients and a specific type of interventions. This is a strong mode mainly advocated by doctors and it has a evident research connotation. By this I mean a certain distance from the everyday practice of taking care of patients. The locations where the collective works to produce and reproduce heart transplant as treatment-centred is in meetings among doctors in the National Hospital, in meetings with the larger community of surgeons performing transplants, for instance in specialized conferences, and in research articles published in specialized medical journals.

In this mode, the identities of patients are not present. Data are collected, aggregated and analysed with statistical techniques. The information artefacts that contribute to the production and reproduction of this mode are many. The EPR and the paper-based patient journal, the Datacor system, Dbase, and the Scandiatransplant system are the most central. The paper based patient journal is used when there is the need for data registered before the implementation of the EPR. The EPR is not made for statistical and aggregated data analysis but it is used as a major source of data for follow up studies: data can be extracted by reading the physicians' and nurses' text narratives. Differently, Datacor is an activity based database, and it is the main system used for aggregating data. Thus is possible to calculate for instance the average stay of the patients in the ICU, the average use of the heart and lung machine during the surgery, or the average age of the patients undergoing transplantation. These calculations create parameters that are then related in order to assess for instance the correlation between age and risk factors. Additionally, one of the transplant surgeon uses a personal database for (i) counting the exact number of procedures performed, (ii) checking with the national people registers to control data on deaths; (iii) having the information needed to be refunded for each procedure performed; (iv) extracting data for research purposes.

By aggregating data on previously transplanted patients, their reactions to the immunosuppression treatment, the emergence of side effects and the survival rate in the long run, this mode defines the parameters of acceptability for heart transplant and the tailoring of immunosuppression treatments. It is analysed for instance how patients respond well to the intervention in relation to their age and medical condition. The Scandiatransplant system is also used for aggregated data analysis. The data entered in the Scandia database in Århus are part of the Nordic thoracic transplant register. This mode works also by making heart transplantation in Norway comparable with that of other countries and to regulate a fair distribution of organs among the Scandiatransplant participants. The regulatory system is based on a comparison of aggregated data from each country. In addition, graphics and statistics are also used for teaching and educating. In this mode where representations of the process are produced, the same representations travel to different places, speak to different audiences, become instruments of persuasion in different contexts. It is a way to communicate and interact with the outside: money, project, visibility. So far, these mode works by showing that heart transplantation in Norway is a successful intervention in relation to the parameters set by the international transplant organizations.

6

5.3   Mode III: procedural ordering

The procedural ordering of information looks at the way information is produced, packaged and used to deal with concurrent tasks, and concurrent patients trajectories. Information is used to organize the work of nurses, coordinators and doctors in relation to the many patients that are in the heart transplant process at different stages. Thus, this mode talks of the articulation work required to keep track of multiple patient trajectories at the same time and relies on a network of artefacts and routines to keep these movements organized. Movements relate to patients that are in different stages of the process and are in the hospital in the same day, and patients that are in the same stage of the process but dislocated in various places. For instance, for the first type (same day, different stages) both in the department of Cardiology and in Thoracic Surgery everyday a patient list of the day is distributed to the health personnel and represents an overview on the workload of the day in the department and on "who is taking care of which patient case". Other artefacts are also used to organize the schedule on a weekly basis.

For the second type (same stage, different places), the waiting list for heart transplantation is a good example. The list shows name and data of patients that are in the same stage of the process: they are all accepted for transplantation and they are waiting for a compatible donation. Yet, they are not all in the hospital or coming to the hospital on the same day. For instance, in the waiting time patients could stay at home or be in the cardiology department just for the periodical control, or in the ICU, or in another hospital. Thus, this mode works by planning and scheduling and listing. It is a more invisible mode of using information than the treatment-centred mode. It is closely related to the articulation of work and allocation of time. But also to making visible the co-existence of many trajectories.

5.4   Mode IV: planning ordering

In the planning-centred ordering information is produced and collected to be able to make visible and manage heart transplantation as a surgical procedure between donor organ and recipient. This mode generates information to be used in the future in a specific envisioned scenario: the sequence of events right before the surgery. In this mode information are organized to minimize uncertainties once the matching is decided. Specifically, this mode works in the practices in two different directions.

On one side it defines as much as possible the temporal and spatial boundaries of the transplant surgery: main artefacts in use are the donation plan and the waiting list. The boundary-constructing part is very visible in the work of the transplant coordinators in planning for the travelling of the patient to the hospital. The central artefact used to organize information is the donation plan. This form requires to enter the specific contact numbers of the patient which are on the waiting list, and it also lists all the actors that need to know about this patient, where he leaves, and how to contact him/her. Another central artefact in this mode, is the waiting list. Specifically, to limit as much as possible the uncertainties related to the patient/recipient matching, it is important that the list is accurate and updated. The accuracy of the data is secured by certain work procedures. For instance, the accuracy of the blood typing is critical. When in the heart meeting is decided to accept the patient as recipient, IMMI receives the acceptance form. This is accompanied by copies of blood grouping previously performed, so to show that the patient has been already ABO typed more than once with the same result. In this mode, heart transplantation is represented by the waiting list: an essential data set as accurate as possible and as updated as possible. But then the other side of the process, the one dealing with the donation, has to be organized so to produce also accurate data and updated data on the donation process. This is the task of the transplant coordinator in surgery. They are the ones extracting the critical information on the patient-donor case to enable the surgeons to assess if the donation is acceptable or not. When the coordinators collect all key information, they call the transplant surgeon on duty.

On the other side, it has to rely on the flexibility of schedules and plans: the transplant surgery happens when the harvesting of the donor's heart is possible and this depend on the contingencies of the donor's condition. The transplant surgery is always an emergency procedure and usually performed during the night or on Sundays. Yet there is also the flexibility to decide when to start the

7

harvesting procedures as donors are kept breathing artificially. All patients are prepared before hand: they are evaluated and screened and put on the list as elective cases, but the timing of the operation is emergency in comparison with the other activities they do in the department. They have an operative planning in the department based on the concept of 'avoiding bottlenecks': the ward, the UA, the ICU are managed to handle a certain number of patients for surgical treatment each week and in addition, a number of real emergency cases for instance acute cardiac cases and acute vascular cases.

5.5   Co-ordering

At any given time and place there are many modes of ordering at work. The four modes I have identified are not separated and isolated but coexist in the practices. For instance in certain situations the transplant coordinator would be very concerned with collecting the information on the donation to inform the surgeon for a possible transplant, while in other situations she would use the same information and aggregate data to teach physicians about the importance of considering donation of organs from dying patients. This coexistence can be harmonious but can also create contradictions and tensions. For instance, the patient centred and treatment centred mode are more visible than others and more dominant, but there are other more silent modes. For instance, the patient centred mode does not work well for the communication between departments. Heart transplanted patients are often requested to have a specialized dermatological visit in the Dermatology Department and they come to dermatology with their big heavy paper based records where analysis reports, letters, notes, results are filed. Information is fragmented and distributed in a variety of paper forms. It is difficult to find the relevant information on the spot. Physician and nurses from different specialities have different requests to the record, and this interdisciplinary order is not supported. Similarly, the need to integrate information between professions (nurses and physicians) is also not supported. For instance, in the patient record (both paper and electronic) nurses notes and documents, and doctors' reports from visits and exams are registered in different sections and rarely doctor and nurses read each other notes.

6   DISCUSSION

The infrastructure of the heart transplant process is made of a diversity of information system, paper forms, binders, places, people, competencies, work routines, regulations, classification schemes and more. It supports a process of transformation of the patient to recipient and to heart transplanted patient. It supports the organization of the donation and the managing of the donor information and the recipient information in order to make the best match. It supports the use of information to set the standards of acceptance of candidate recipient into the process. It also supports the everyday articulation work in the various departments and across department: for instance the order/results interactions with the laboratories and service departments and the planning of visits and exams. The above analysis, based onthe concept of modes of ordering is an attempt to picture this complexity without simplifying it.

The phenomenon of using technology in multiple situated practices is framed from an ANT interpretation by asking: what are the effects of the multiple situated use of technology? Adopting an early ANT conceptual framework, the answer to this question would look for a stable effect or the negotiating attempts to reach a stable effect. The concern would be on identifying the strategies by which the multiple perspectives of the users in the multiple context are translated into an aligned network. Yet, such analysis would tell only one part of the story. In my interpretation, the data from the case study presented in this thesis show that the strategies at work are more than one: for instance there is an interest to extract data about heart transplant in an aggregated way, but there is also an interest in the detailed narrative from cardiac visits. There is an interest to keep the donation and the transplant data separated, but here is also an interest in connecting them and be sure that the link is traceable.

The focus on multiple orders in not new. Specifically, it has been studied how structures are embedded into technologies and during use of technologies those structures are appropriated by human actors.

Orlikowski argues how that approach has limitations when dealing with ongoing changes in both technologies and their use: in particular for groupware and the Web (Orlikowski, 2000). Thus, she suggests to extend the structural perspective by proposing a practice-oriented understanding of the interaction between people and technology. She distinguish between embodied structure and embedded structure, and between appropriation and enactment. However, Orlikowski understanding of enactment is limited to individual perception of technology use. The focus on the individual limits the possibilities of the technology as actor. Differently, the research presented in this paper supports existing literature theorizing and analyzing the role of technology in work practices in a relational way. For instance, Berg describes the accumulating and coordinating activities of information technologies (Berg, 1999). Similarly, Hartswood et Al. show how, in the work practices of a toxicology ward, the patient record is "brought to life" in different ways to present a particular and organizationally adequate representation of the current state of affairs (Hartswood et Al., 2003).

In addition, the concept of multiple order or universality has been explicitly discussed in Berg and Timmermans's account on the introduction of Advanced Cardiac Life Support (ACLS) algorithms, and mathematical techniques of decision analysis in medical practice (Berg and Timmermans, 2000). The authors argue that technology driven rationalization does tend to or produce a single order or universality. In particular, they criticize many early ANT and social constructivist studies, where it is largely argued that through time a disorder can become a (single universal) order and vice-versa. In the case of the rationalization of medical work, this implies that "rationalization" as such does not constitute a single universal order. Leveraging the two cases on the introduction of the ACLS and the statistical/mathematical decision analysis techniques, Berg and Timmerman show how (i) technology driven rationalization can produce multiple orders or universalities, and (ii) the production of a order generates a new dis-order. Further, Berg that suggests studying different logics in medical work: *"in debating and analyzing logics we are no longer focusing on either physicians or tools. The theoretical unit of attention is no longer what a medical staff member decides, or what a decision-support techniques does. Different logics can be discerned and discussed irrespective of in what or who these are embedded. It is not that logics are not performed and embodied in concrete practices (…) these logics constitute discernible patters that cut across the categories of "tool" and "human practice" and can be debated as such"* (Berg, 1997b, page 172-3).

Accordingly, I argue that by making use of the concept of modes of ordering to look at information in use, different coexisting modes of information in use can be identified. Technologies come to work in specific directions because they take part in producing and reproducing ordering modes of information in use. And artefacts are written into them in varying degrees. This makes the infrastructure supporting the various logics of information use, not a unity: the infrastructure itself take part in performing multiple information logics. Hence, modes of ordering is a way to see processes across the situated practices by making explicit the multiple singularities, or coherences the process produces.

7   CONCLUSION

The paper shows how the heart transplant process relies on a process-oriented infrastructure where the various information artefacts are interdependent. It also analyse the way the infrastructure works according to different coexisting logics of information use. The last section discusses the identification of the different logics as a way to articulate the complexity of information infrastructures as complex objects which is coherent in multiple ways. The implications of this discussion are the following.
First, identifying multiple logics at work in technologies in use, it is a way to question how to intervene in infrastructure development: for instance a component which is marginal in one logic can be very relevant in another logic. How to intervene, and what consequence will an intervention have?
Second, identifying multiple logics at work is a way to question the ownership of the process itself, and to interfere with managerial approaches advocating process redesign in hospitals to improve efficiency and performance in care delivery.

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