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Jon W. Beard
Purdue University, jwbeard@purdue.edu

Berkeley Keck
United Network for Organ Sharing, keckbm@unos.org

Tim O. Peterson
Texas A&M University, tim.o.peterson@ndsu.edu

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INFORMATION SYSTEMS AND HEALTH CARE –VII WHEN SUCCESS RESULTS IN FAILURE: THE CHALLENGE OF EXTENDING THE IT INFRASTRUCTURE TO SUPPORT ORGAN PROCUREMENT AND TRANSPLANTATION

Jon W. Beard,
Krannert School of Management
Purdue University
JWBeard@purdue.edu

Berkeley Keck,
United Network for Organ Sharing

Tim O. Peterson,
Mays College of Business
Texas A&M University

ABSTRACT

Xpedite was a computer-based information system developed by the United Network for Organ Sharing (UNOS) to enhance organ procurement and placement from cadavers. Using state-of-the-art development approaches and technology at the time of its development, *Xpedite* was built around Lotus *Notes*®, facsimile machines, and alphanumeric pagers. It was developed to integrate and streamline the collection, transfer, and exchange of data on available organs more fully. The concept was to shorten the time from organ availability (i.e., donor death) to transplant, thus reducing organ wastage. *Xpedite* met design and operational performance goals (i.e., a reduction in placement times and data errors), yet its operation was terminated after barely twenty-four months of operation. Adoption of the new technology throughout the transplant community was limited due to inexperience with integrated information technology systems and the resistance to change that accompanied *Xpedite*'s launch. The individual and organizational resistance was a surprise to UNOS. The technical and organizational lessons learned from this experience helped UNOS with developing subsequent information technology infrastructure components. The complexity of the technology support environment and low levels of user adoption for *Xpedite* ultimately led to an evolution beyond this tool, resulting in an Internet-based environment that would be more robust, easier to maintain, and better able to support user needs.

Keywords: implementation, rapid application development (RAD), resistance, power, organizational coupling, organ transplantation

I. INTRODUCTION

> *The real crisis in transplantation today is the critical shortage of organs available for transplant. For all patients awaiting a life-saving heart, lung, liver, kidney, or pancreas, 10 will die – today and every day – because an organ was not available. Increasing the supply of donated organs should be national policy.*
> James M. Burdick, M.D. Transplant Surgeon, Johns Hopkins Medical Center, President UNOS Board of Directors [June 1996-June 1997]

Among lifesaving medical procedures, organ transplantation from a cadaveric (i.e., non-living) donor is unique. Like most medical procedures, organ transplantation relies upon the skills of the recipient's physician, surgeon, and transplant team. In addition, it requires the "donation" of one or more organs from a person who is declared legally dead (i.e., in the United States, officially brain dead) for transplantation in one or more recipients. Unfortunately, because not enough organs are available for all who await a transplant, it is important that every available organ be used in these life-saving transplants.

Organ viability for transplantation is measured in hours. Therefore, careful and timely coordination is required to match and place donor organs with recipients,[1] communicate essential medical information between donor and recipient hospitals, and recover, preserve, and transport organs, often over great distance, before the transplant can take place. A breakdown in any element of this process can lead to the wastage of desperately needed organs and perhaps the death of a potential transplant recipient before a transplant can occur.

Xpedite was a client-server information technology environment developed to facilitate and streamline the organ procurement, placement, and transplantation process. It was an integrated system built around Lotus *Notes*®, SkyTel pagers, and facsimile machines [OIS, 1995; Rapid Transplants, 1995]. While it wasn't expected to eliminate the organ shortage, *Xpedite* was designed to assist in better managing the procurement and placement of available organs while reducing organ wastage by extending information technology (IT) support across a broader range of transplant-related activities. Further, it was an attempt to start the consolidation and integration of separately developed independent IT systems. But the technology itself was not sufficient to improve the procurement and placement process. Organizational issues, such as resistance to change, community interdependencies, or organizational coupling, individual and unit power, and organizational inertia, also need to be actively considered as contributing factors in *Xpedite*'s limited success and ultimate demise.

This paper proceeds as follows. First, a brief overview of the organ procurement, placement, and transplantation process is presented to provide a context for the organization environment and its IT infrastructure (Section II). The process of analysis, design, and implementation for *Xpedite* is presented in Section III. The problems encountered in the development and implementation of *Xpedite* and its subsequent termination are considered in Section IV. Section V explores the lessons learned by the United Network for Organ Sharing (UNOS) in continuing the development and integration of their IT environment.

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[1] Because up to eight organs, i.e., heart, liver, pancreas, intestines, two kidneys, and two lungs, may be donated, the process can be arduous. This list does not include blood, bone marrow, corneas, or other body parts or components.

II. OVERVIEW OF ORGAN PROCUREMENT AND PLACEMENT: UNOS – THE UNITED NETWORK FOR ORGAN SHARING

The United Network for Organ Sharing (UNOS) coordinates the allocation of organs from cadaveric donors throughout the United States [UNOS, 1994]. It is a private, nonprofit corporation, formed in 1986 following the passage of *The National Organ Transplant Act (NOTA), P.L. 98-507* in 1984. UNOS operates the national Organ Procurement and Transplantation Network (OPTN) under contract with the U.S. Department of Health and Human Services. As administrator of the OPTN, UNOS maintains a computerized waiting list of all people awaiting an organ transplant in the U.S. and assists in the development of national guidelines for organ allocation. Under a separate contract, UNOS also maintains the Scientific Registry of Transplant Recipients. This registry consists of data on all U.S. transplants and tracking information on all transplant recipients as long as they survive with a functioning transplanted organ. All transplant centers, organ procurement organizations, and histocompatibility[2] laboratories involved in transplantation are members of UNOS. At the time of *Xpedite's* design and launch, UNOS membership stood at 443[3] [UNOS, 1997].

In summary, UNOS's two fundamental missions are:

1. to assist in procuring and placing organs for transplantation, and
2. to maintain a database of transplant recipients to support research directed at improving organ allocation criteria and national policy and to improve the transplant process.

To fulfill the requirements of its contract with the federal government, UNOS must maintain and continue to develop and extend the IT infrastructure to support and coordinate organ procurement and transplantation in the United States. *Xpedite*, the project reported in this article, was determined to be the important next step in the IT evolution at UNOS, improving both organ placement and better integrating the broader IT environment.

TRANSPLANT WAITING LIST

With the passage of NOTA in 1984, the improvement in transplant procedures and immunosuppressive therapies, and the centralization and coordination of organ matching through UNOS, the number of transplants in the United States grew significantly in the last 20 years. The number of transplants of cadaveric organs rose from 10,795 in 1988, to 15,915 in 1995 [UNOS, 1997] to 18,653 in 2003 [UNOS, 2004]. However, during this same time frame the OPTN waiting list grew from 16,026 in 1988 to 50,384 (updated data for 1995 as of January 15, 1997).[4,5] Growth of the waiting list continued in subsequent years, with current registration data showing 95,602 people on the waiting list [UNOS, 2004]. Table 1 summarizes this data.) Some speculate

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[2] Histocompatibility is a state or condition in which the absence of immunological interference permits the grafting of tissue or the transfusion of blood (*American Heritage Dictionary*, *Second College Edition*, 1982).

[3] These include 281 transplant centers, 4 consortium members, 54 independent organ procurement organizations (OPOs), 55 independent tissue typing laboratories, 12 voluntary health organizations, 8 general public members, and 29 medical/scientific organizations.

[4] Immunosuppressive therapies are combinations of drugs, including steroids, to suppress a natural immune response of an organism to antigens produced by a foreign body; i.e., prevent the body from "rejecting" a transplanted organ by immune system attack. This attack will damage and subsequently destroy the transplanted organ.

[5] UNOS policies allow individuals awaiting an organ transplant to be listed with more than one transplant center (i.e., multiple listing) and for more than one organ (e.g., heart, lung, kidney). Thus, the number of registrations may be greater than the actual number of patients.

that another 50,000 to 100,000 people in the U.S. may need an organ transplant, but are never placed on the UNOS waiting list for a variety of medical and financial reasons [UNOS, 1997].

Table 1. Summary of Transplant Waiting List versus Organ Donors – Macro-Level Data

	Total No. of Potential Recipients on Waiting List[a]	Total No. of Deaths while awaiting Transplant[b]	Total No. of Organs Recovered for Transplant	Cadaveric Donors Organs	Cadaveric Donors	Living Donor Organs
1988	16,026	1,504	13,966	12,142	4,080	1,824
1989	19,095	1,684	14,769	12,851	4,011	1,918
1990	21,914	1,986	17,124	15,001	4,509	2,123
1991	24,719	2,410	18,030	15,603	4,526	2,427
1992	29,415	2,636	18,609	16,038	4,520	2,571
1993	33,352	3,099	21,013	18,108	4,861	2,905
1994	37,609	3,416	22,368	19,262	5,099	3,106
1995	43,983	3,723	23,247	19,749	5,362	3,498
1996	50,169	4,247	23,481	19,681	5,416	3,800
1997	55,557	4,812	24,127	20,061	5,478	4,066
1998	62,415	5,507	25,385	20,815	5,793	4,570
1999	68,303	6,973	26,177	21,133	5,824	5,044
2000	75,006	6,612	27,433	21,499	5,985	5,934
2001	80,586	7,184	28,530	21,921	6,080	6,609
2002	82,749	7,262	29,033	22,404	6,190	6,629
2003	Not available	7,073	29,731	22,902	6,457	6,829
2004	92,277	7,060	32,150	25,146	7,150	7,004
2005[c]	95,602	1,598	8,152	6,505	1,881	1,647

[a] The data in this column was derived from Table 5, p. 24, of the 1997 Annual Report, The U.S. Scientific Registry of Transplant Recipients and The Organ Procurement and Transplantation Network, Transplant Data 1998-1996, UNOS and the 2004 Annual Report found at the UNOS/OPTN website at http://www.optn.org/AR2004/default.htm (retrieved 7/10/05).

[b] The data in this column was derived from Table 7, p. 26, of the 1997 Annual Report, The U.S. Scientific Registry of Transplant Recipients and The Organ Procurement and Transplantation Network, Transplant Data 1998-1996, UNOS and Table 1.7 of the 2004 Annual Report found at the UNOS/OPTN website at http://www.optn.org/AR2004/default.htm (retrieved 7/10/05).

[c] Data is for a partial year, through March 31, 2005, the most recent data currently available.

ORGAN PROCUREMENT AND MATCH FOR TRANSPLANTATION

Since it is illegal to buy or sell human organs for transplantation in the United States, "the gift of life" is a donation by the donor's family. Organ recipients do not "buy" the organ, although there are other substantial medical- and transplant-related expenses. Instead, all potential recipients for an organ transplant are placed on the OPTN transplantation waiting list (i.e., a database) maintained by UNOS. This waiting list is accessible 24-hours a day, 7 days a week, 365 days a year. The criteria for being placed on the list were established through an advisory process of participating physicians, surgeons, medical organizations, other significant stakeholders (e.g., actual transplant recipients and recipient family members), and public comment [Koch, 1999; Pritsker, 1998; UNOS, 1999]. When a recipient's name is added to the waiting list, their medical profile is entered and stored in the UNOS database. Instead of being added to an already ranked list, the recipient is added to a "pool" of patient names. The "pool" approach is used because of changing availability of recipients due to fluctuations in health and varying match characteristics due to differences in histocompatibility between donors and potential recipients; i.e., not all organs are suitable for all candidate recipients [Klein et al., 1994; *Wall Street Journal*, 2004].

When an organ donor becomes available (i.e., when someone is pronounced brain dead), the facility with the donor accesses the UNOS computer with donor information; the UNOS *Match* program generates a ranked list of patients based on the donor information.[6] Rankings are determined by both medical and scientific criteria (i.e., UNOS policies and pre-established priorities), such as tissue match, blood type, age, body size, length of time on the waiting list, immune status, and medical urgency (for heart, liver, and intestinal organs). The criteria are under constant assessment and scrutiny for modification through analysis and evaluation of the Scientific Registry of Transplant Recipients to allocate the scarce resource (i.e., organs) better for transplantation.[7] The location of both the donor and recipient are also important factors in developing the ranking [Johannes, 2004; Koch, 1999; Pritsker, 1998; UNOS, 1997].

Historically, an organ procurement coordinator at the donor hospital then makes a series of individual phone calls to several transplant centers identified through the *Match* system. Detailed donor information is faxed to the transplant teams of the viable recipients for immediate assessment. Potential recipients within the local area typically are given first priority; if no suitable matches are found, the search is broadened to a larger regional focus, and then nationwide. Offers are made in sequence according to a priority ranking of potential recipients; the coordinator often must repeat the process several times for a given organ if one or more centers decline the offer. Since each center may take up to one hour to respond to an offer, several hours may pass before an organ is placed. Offers are also made individually for each organ available (e.g., kidneys, liver, pancreas, intestine, heart and/or lungs), adding to the time consumed by this process and requiring additional coordination of donor resources. During this time, the (officially "brain dead") donor's vital functions are being sustained artificially to preserve organ viability. This process may last from a few hours to a few days. Should artificial respiration and circulation end prematurely, the opportunity to recover any organ is lost. The intended transplant recipient may die if another donor is not found in time.

The top person on the ranked list often will not receive the transplant. The individual must be available (i.e., they can be located, contacted, and able to reach the transplant center quickly), healthy enough to undergo major surgery, and willing to be immediately transplanted. The willingness to be transplanted immediately is important. For many recipients a transplant can mean a new lease on life up to an almost normal life expectancy and active life. Unfortunately, for some, a failed transplant process or poor match between the organ and recipient can mean almost immediate death, sometimes within hours of the surgery or even during the surgery. Therefore, a laboratory test is also often given to ensure compatibility between the recipient and the organ to be transplanted. Once the recipient is identified, surgery is scheduled and the transplant takes place within hours. The procurement and placement process is shown in Figure 1.

ORGAN SHORTAGE

Unfortunately, fewer organs are available than the number of people awaiting a transplant. Increasing the donor pool remains the single best method for eliminating the organ shortage. Extensive efforts have been made to increase the number of donors. For example, advertising campaigns encourage people to become organ donors and to indicate their preferences to their families,. The appearance of organ donation as a plot device in several popular TV shows increased [cf. Johannes, 2004; UNOS Update, 2001]. Yet, in the mid-1990s, on average, ten

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[6] Since the data entry process is largely manual, it often takes several months for complete and correct information on a transplant to be entered into and verified in the UNOS databases. Hence, data for a specific year are often not considered 'complete' until many months later.

[7] Each donor will generate a different ranked list due to differences among individuals.

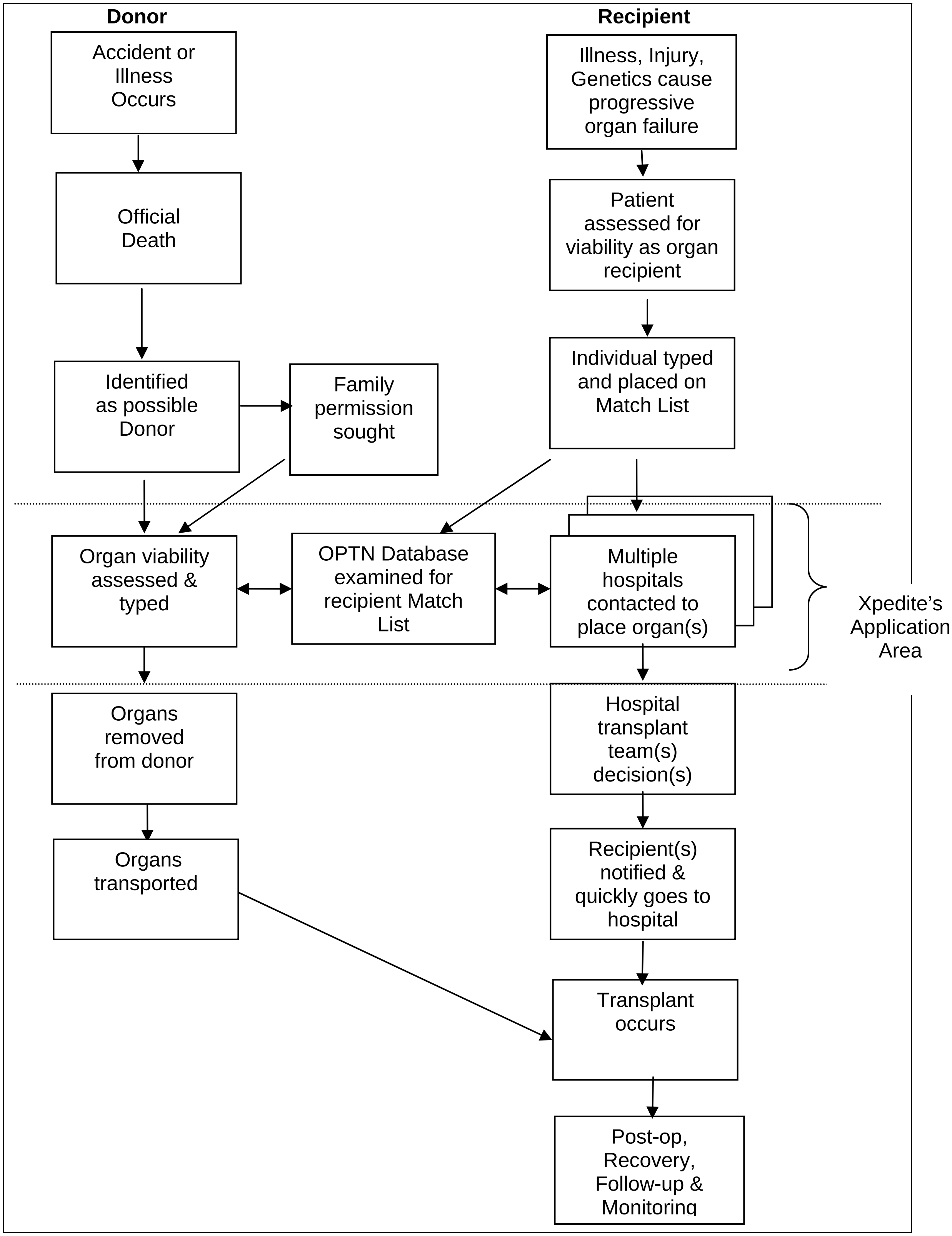

Figure 1. Overview of Organ Procurement, Placement, and Transplantation Process

people from the waiting list died per day because an organ was not available. Currently, the number is even larger, with an average of almost 20 people per day dying before they can receive a transplant. The number of cadaveric donors has not grown significantly since 1988 (when UNOS began tracking organ transplants). Reasons for the limited supply include improvements in medical treatment for traffic-accident, knife-wound, and gun-shot victims; the increase in transmittable disease (e.g., HIV/AIDS, hepatitis, etc.) among the general, and especially the younger, population; medical personnel neglecting to seek permission for procuring organs from the recently-deceased's family; and a reluctance to donate organs for personal and/or religious reasons.[8] The percentage of discarded organs (i.e., those that are not used) increased between 1988 and 1995 to as much as 9 percent. Given the limited supply and increase in the number of discards, it was desirable that every available organ from the existing donor pool be effectively "utilized."

Utilization is defined as maximizing the number of organs available per donor and minimizing discard rates. Multiple organ donation (i.e., procuring two or more organs from the same donor) increased steadily over the years, with 81 percent of donors in 1993 involving multiple organs. Unfortunately, discard rates also increased. Removing multiple organs increases the time between death, placement of the available organs, and their removal and transplantation. The need for a larger donor pool led to the use of organs from individuals from a broader range of ages, especially older donors. Organs from older donors are typically more difficult to place, leading to prolonged ischemia.[9] Using organs from older donors is one of the contributing factors to the increasing discard rate [UNOS, 1997]. All of these delays may result in delayed graft function for kidneys and primary non-function for hearts, livers, and lungs when transplanted, or to organ discards. Thus, a reduction in time to place and transplant a donor's organs can lead to a reduction in organ wastage. [10]

III. *XPEDITE*

SYSTEM APPROVAL AND DESIGN CRITERIA

From 1991 to 1995, UNOS studied ways to streamline transplant data collection and data transmission using on-line computer technology. While several areas in the process were identified for enhancement and development, the most critical domain identified was that of organ placement: accessing a list of potential organ recipients for a given donor's organs, contacting the transplant centers where the patients are registered, and conveying donor information to those centers to speed the decision process [Klein et al, 1994]. This portion of the transplant process is indicated in Figure 1. For example, in 1993, placement time averaged 3.4 hours per organ (range 0.5 to 37 hours) for the organs processed through the UNOS system [UNOS Handout, 1996]. When multiple organs are being placed, the cumulative placement time required to place all of a donor's organs can easily stretch beyond 24 hours. This realization was the genesis for the creation of *Xpedite*.

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8 Some recent advances in medical knowledge and technology has broadened the pool of available organs through living donor grafts and transplants for some organs (e.g., livers and kidneys) in the very late 1990s.

9 Ischemia is a prolonged period without a blood supply. Too long a period of ischemia will result in a reduction in organ viability.

10 An additional source for some organs is from living donors. These are generous people who are willing to donate all of an organ (e.g., kidney) or portion of an organ (e.g., liver, lung). They may or may not be biologically related to the recipient. The number of living donors increased steadily and now accounts for approximately 25 percent of the total number of transplants performed each year (Table 1). Because the placement of these organs is not as time critical as it is for cadaveric organs, *Xpedite* was not developed to support this portion of the organ placement domain.

In 1994, UNOS received approval from its Board of Directors to begin developing a computer-based organ information system, later named *Xpedite*, to collect, process, and disseminate essential donor information. Three state-of-the-art concepts drove *Xpedite's* development.

1. It was realized that the support of organ procurement and placement heavily resembled sales force automation. This insight was used as a guiding conceptual framework for system functionality and flexibility.

2. The outcome was to be a client-server environment providing the procurement and transplant centers autonomy in transferring, manipulating, and using the available information with centralized database support by UNOS.

3. Given the limited resources, the need for a high-quality and high-reliability software environment, and the speed required for development and activation, a Rapid Application Development (RAD) methodology was used.

SALES FORCE AUTOMATION

The conceptual framework for *Xpedite* was based on the existing and then relatively new paradigm of sales force automation. In sales force automation, the sales force is often outfitted with laptop computers, hand-held PCs, and even pen-based computers [O'Brien, 1996]. This approach improves the individual productivity of the sales people, and can significantly enhance the capture, recording, merging, and analysis of relevant sales data for use by corporate marketing and other organizational decision makers. In turn, the marketing area can then support the sales people better. Ultimately, this increased and improved coordination among sales and marketing can yield improvements in organizational productivity and responsiveness.

For organ procurement and placement, the goal is the quick and accurate capture of relevant data, transmission of that data to the appropriate decision makers (i.e., the transplant teams), more rapid decision making in placing an organ, and better coordination of communication among the various constituencies. Enough potential parallels existed between the two notions to warrant investigation of the idea as a conceptual model on which to build the system to support organ procurement and placement.

CLIENT-SERVER ENVIRONMENT

Throughout the early 1990s, client/server computing was touted as the model for enterprise-wide computing for the 21st Century [Beyer, Newell, and Hurst, 1994; Guimares and Igbaria, 1997; O'Brien, 1996]. Client/server computing is an information architecture consisting of an integration of computer hardware, software, and people, where computing power and information are distributed across an interconnected network of computers. The client, i.e., the user workstation or personal computer, is able to perform most of the information processing tasks locally. These tasks include data entry and update, database inquiry, transaction processing, report generation, and other interface and decision support activities. Network servers manage network operations and overhead, collaboration and communication within and among workgroups, and the sharing of application programs and data throughout the network. Client/server computing is directed at allowing the large, centralized server computers to concentrate on those tasks for which they are best suited, such as network communications, high-volume transactions, network security and control, and database management and maintenance. Client machine and user activities can, therefore, be more responsive to and focused on their own local application effectiveness and efficiency.

For organ procurement and placement, this type of independent, yet integrated, network of computers was perceived as the appropriate framework for design. The clients are the desktop and laptop computers used by the procurement officers and transplant teams; the server is the main computer system at UNOS headquarters that contains the OPTN database. The client machines are used by the organ procurement coordinators to enter the donor-relevant data and transmit it to UNOS. The *Match* system database identifies potential recipients for each organ available. These lists are sent back to the organ procurement coordinators, who then begin the process of notifying the transplant centers of potential recipients of the availability of one or more organs for transplant. The transplant centers can then access the relevant data via the UNOS server and make a decision on whether to accept the organ for transplantation. Coordination can then proceed between the various medical centers for organ removal, transportation, and transplantation.

RAPID APPLICATION DEVELOPMENT (RAD)

Rapid Application Development (RAD) is a software application development methodology first elaborated by Martin [1991]. The goal of this methodology is to "use people and automation to achieve higher quality applications than those built with traditional lifecycle" approaches (p. vii). RAD's goals are high quality, lower cost, and more rapid system development than more typical approaches. These goals are accomplished by using CASE-based toolset(s), rapidly evolving prototypes, and significant user involvement in the design and development process. In a competitive business environment, speed (e.g., to manufacture a product, fill an order, provide an answer, construct an application) is increasingly important as organizations look for ways to outperform the competition.

For organ transplantation, speed is of the essence in placing organs to avoid organ wastage and to possibly save a life through a successful organ transplant. The development of a more functional information technology-based system to support organ placement needed to be accomplished in a short time frame and correctly aligned with the needs of the transplant community [Bruno, 1998].

PRELIMINARY SYSTEM DESIGN AND TRIAL(S)

Initial approval to investigate and build the system was provided by the UNOS Board of Directors in 1994. This board is made up of representatives from throughout the transplant community, including physicians, nurses and other medical staff, organ procurement representatives, and both transplant recipients and family members of transplant recipients. The initial idea and most of the development effort was concentrated within the IT area at UNOS. At the start of the project, the development team decided that a prototype would be built using Rapid Application Development (RAD) methodologies to get quick feedback on the viability of the concept.

Because of the nature of the task and the uncertainty about its usefulness in the organ procurement environment, many ideas needed to be demonstrated and tested along the way. The RAD approach would facilitate this low-risk experimentation of system features and design. For example, during the prototype phase, donor information captured and sent to UNOS was used to actually place organs. The original idea was to build a pen-based application using wireless communications to collect donor information in the field. The data would be collected via laptop, sent back to UNOS, and distributed to the transplant centers.

Six pilot sites from across the U.S. were selected for this trial. During the initial trial, coordinators at six organ procurement organizations (OPOs) affiliated with the donor hospitals used portable computers to enter pertinent donor data electronically using a common data format. This process eliminated the use of handwritten donor sharing forms. The results determined that legibility was greatly improved, the forms generated were more complete, and the time required to enter donor data was comparable to the written method. This trial verified that organ placement could be enhanced through this technology by reducing initial data collection errors, transmitting a more complete set of donor data to support better decisions, while equaling or reducing (i.e., improving) the decision time frame. Each of these enhancements was important in improving the procurement and speeding the organ placement process.

The preliminary study also revealed several important facts that changed the direction of the effort.

1. Electronic data collection was important, but communication between the donor site and the transplant centers was vital. Both fax and electronic document capability were necessary. Paging was sometimes required to get someone's attention to act on the required decision. While it was originally felt that wireless communication was an important consideration and goal, many donors come from remote areas where wireless communication was difficult or impossible in the mid-1990s; therefore, the wireless approach was dropped from the agenda.

2. Organ procurement coordinators wanted the system to integrate with the UNOS computer *Match* system. Integration would enhance the organ placement process by providing greater autonomy such as giving end-user computing capabilities to the placement coordinators.

3. The system was required to work across various technology platforms, such as UNIX, Macintosh, and IBM-compatible personal computers, to preserve the existing technology investment among the various procurement and transplant centers.

4. Instead of the anticipated pen-based approach, users actually preferred the keyboard for data entry.

5. These goals had to be met with the two principal constraints: the system needed to be developed quickly and cheaply.

To meet these requirements, UNOS needed technologies that could satisfy the infrastructural aspects of linking devices and people along with a rich applications environment. The desire was to use off-the-shelf ideas and solutions where possible. Custom programming was limited to the interfaces. Based on this trial, a subsequent project to integrate the IT infrastructure across all phases of organ procurement and placement was initiated. This meant integrating the already-existing *Match* system and the Scientific Registry of Transplant Recipients with the new components that would automate the collection of donor data, the distribution of match results, and the communication and coordination among the transplant centers. In other words, aligning the enhanced system with the strategic efforts of the organization became a paramount goal. The original name for the project was already copyrighted, so *Xpedite* was chosen.

The prototype for *Xpedite* was developed in Visual Basic using the RAD methodology. Its user interface was elegant but its communication capabilities were slow. Since improved and more rapid communication was one of the primary justifications for *Xpedite*, another approach was used. Lotus *Notes*, with capabilities such as data replication, faxing, paging, e-mail, on-line collaboration, and possible Internet connections, was selected as the software environment for supporting the system. *Notes* could meet both planned and potential future communication needs. In addition, *Notes* was compatible with multiple platforms.

FINAL DESIGN, CONFIGURATION, AND IMPLEMENTATION

Xpedite became fully operational at UNOS headquarters and a number of organ procurement sites across the country in the fall of 1995. Its performance exceeded the goals defined at the start of the project. It took advantage of the *Notes* platform to replicate donor information from the field to UNOS and improved communication and coordination among the various participants. Although the goal was to use as much off-the-shelf software as possible, in the end much of the system required customization to meet performance and quality criteria for organ placement. In addition, although it was to be platform transparent, only IBM-compatible interfaces were implemented fully. Extending *Xpedite* to other platforms was a long-term goal, but looked to be time-consuming and expensive.

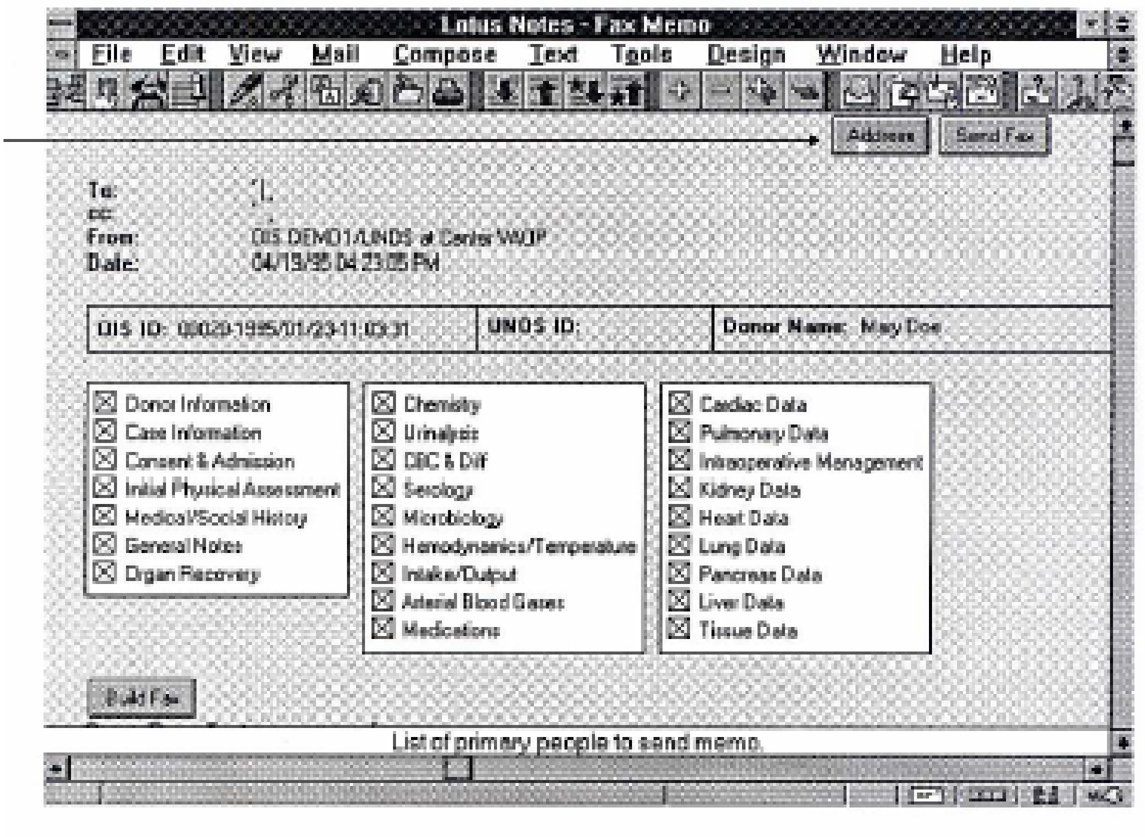

Figure 2. Sample *Xpedite* Screen with Lotus *Notes* Interface

With the revised design, the organ procurement coordinators collected donor data using portable computers (pen optional) and replicated this information back to the UNOS *Notes* server. The server interfaced with the computer *Match* system and transmitted the results of the match back to the coordinators. The coordinators could then contact the often geographically dispersed transplant centers via the SkyTel paging system to let them know that a particular organ was available and that their potential transplant recipient is ranked high on the match list. For example, it could say "a kidney is available for patient x" and that "patient x is ranked second on the match run." The transplant center for the potential recipient could dial into the UNOS *Notes* server to replicate all information about the donor or use Phone *Notes* to request a fax of the donor information through a fax gateway. This process was designed to occur simultaneously at multiple transplant centers for all organs being placed instead of sequentially as it was historically accomplished. Without this new technology infrastructure, simultaneous transmission of data on various organs would be impossible.

In addition, much of the same on-line donor information could be captured from *Xpedite* and entered directly into the Scientific Registry of Transplant Recipients database, reducing the amount of time and effort previously required for manual data entry. Productivity was enhanced for UNOS staff and organ procurement coordinators in the field. It was believed that this approach might increase the number of usable organs that could be recovered from a given donor due to timely and more widespread transmission of organ offers. The result was a more efficient management of the organ placement process, improved organ utilization, and decreased donor hospital time and costs. These goals were achieved in the limited implementation of the system.

SYSTEM BENEFITS

Several benefits resulted from the introduction and use of *Xpedite*. The obvious benefit was the reduction in time required to place available organs for transplantation.[11] Once an individual is pronounced dead they are assessed as to whether they may be viable organ donors. If determined to be a candidate for organ donation, permission is sought from the immediate family to acquire the organ(s).[12] Prior to organ recovery, donors are maintained (i.e., circulation and respiration are artificially supported) in expensive critical care facilities. The donor must be kept "alive" while the organs available for transplant are matched with potential recipients.

Once all organs are matched to a recipient (within certain time constraints), the organ(s) may be removed from the donor for transport to the transplant facility. Sequencing and coordinating organ removal is also necessary, meaning that all organs that are to be transplanted must be placed with a recipient prior to the organ removal process beginning, i.e., specific recipients for all organs must be identified and have accepted the organ for transplant prior to the start of organ removal from the donor. The medical costs incurred during the placement process affect everyone through higher insurance rates and increased Medicare/Medicaid costs. *Xpedite* reduced the time donors spent in these expensive facilities, translating into lower medical costs. Finally, donor families, who altruistically consented to donate their loved one's organ(s), often must wait hours until organs are placed and recovered[13] before the body can be released for funeral arrangements. *Xpedite* sped the placement process, which spared the family a lengthy and agonizing wait. This more rapid placement significantly reduced the number of viable organs that went unused.

In addition to saving human life, other significant medical/technical, financial, and humane benefits occurred in conjunction with *Xpedite*'s installation and propagation. The job of the organ procurement coordinator requires intense, focused effort to place organs rapidly and successfully from an available donor. *Xpedite* simplified the job of the organ procurement coordinator by automating much of the placement process in a client/server environment. While data must still be entered into the system, laptop computers can simplify and support this process. *Xpedite* then transfers the donor data to UNOS, where it is automatically disseminated to the appropriate transplant centers based upon the match with potential recipients ranked by the relevant criteria. Unlike the old manual process, with *Xpedite* the coordinator did not have to worry with the details related to distributing the donor data. As a result, the procurement coordinators could concentrate on donor management. The improved communication of important and necessary data resulted in higher productivity and a reduction in stress for the coordinators.

The ultimate goal for *Xpedite* was to link the entire transplant community electronically using Lotus *Notes* as the basis for communications. This would include the transmission of organ donor-specific information, as well as real-time communication among organ procurement coordinators and medical personnel. A significant part of this growth and evolution was to develop an electronic data interchange system that would collect and exchange scientific data on transplant recipients. The ultimate objective was to provide transplant surgeons, physicians, and

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[11] All improvement data is essentially anecdotal. Without an experimental and control group for comparison, it is impossible to state with certainty that *Xpedite* is any "better" than the previous approach. However, the general consensus is very positive and the anecdotal evidence supports a positive assessment.

[12] Although U.S. law supports acquiring organs from an individual who has a signed donor card without any additional consent, the general practice is to also seek permission from surviving family members. The physicians and medical facilities are legally protected, but the additional permission is considered more compassionate to the family, avoids misunderstandings, and reduces the likelihood of "frivolous" lawsuits.

[13] That is, removed from the donor's body.

researchers with an easy method for collecting and sharing scientific data from the Scientific Registry on Transplant Recipients. Communication between all transplant professionals could be enhanced through this system. In addition, e-mail between individuals at different facilities facilitated timely professional contact and discussion where little then existed. Transplant professionals could share ideas and collaborate with ease through discussion databases. Interaction of this type might improve coordination in better procuring, placing, and monitoring transplantation and transplant recipients worldwide. *Notes* could link to the Internet, an emerging goal for UNOS and the organ transplant community at that time. Finally, it was envisioned that this system could ultimately be extended to link transplant programs globally should the need arise. *Xpedite* could even serve as a model for other health care groups in developing systems for managing and disseminating critical information.

XPEDITE'S DEMISE

In spite of its lofty aspirations and the accomplishment of its development and performance goals, Xpedite was never widely adopted within the transplant community. Beyond the six locations used during the prototyping and testing phase, no additional sites fully adopted the communication technology. The fax and replication facilities were used sporadically to improve the exchange of donor and recipient data, but not enough to justify the continued operation of the system. After just twenty-four months of operation, Xpedite was deactivated on December 15, 1997.

Technologically *Xpedite* stretched the limits of software, hardware, and communications. It required real-time communication and interaction among independent organizations that are geographically dispersed. Collaboration and close teamwork between the interface developers, Lotus Corporation, SkyTel, the transplant community, and UNOS staff was essential to the development process. It took the coordination of all concerned to make this project work on time and within the limited budget. The resulting system was a significant achievement in collaborative technology and a landmark enhancement in the efficiency and productivity of the medical professionals saving lives through organ transplantation.

The next section considers and discusses additional factors that may have contributed to Xpedite's limited success.

IV. WHEN SUCCESS RESULTS IN FAILURE

It is far too common for an information system project to be unsuccessful [cf. Standish Group, 1994]. The failures are caused by a variety of factors, including a failure to achieve operational goals. However, it is less common for a system to have a goal that all can support, have top management backing for development, successfully achieve operational goals, and still not be successful due to limited adoption. In this circumstance, the causes of the failure are less certain. While it might be easy to attribute *Xpedite*'s limited success primarily to technological complexity and general resistance to change, the situation deserves some deeper scrutiny and analysis. Following the proposition of Hogarth [1991], what is suggested here is that several familiar, yet often independently considered factors, contributed to this failure. In isolation they may not capture the richness and complexity of the environment. They embody many of the subtle challenges facing organizations in the increasingly integrated and electronically connected environment. These challenges are now explored in some detail.

GENERAL OBSTACLES TO CHANGE

This project faced and endured many obstacles common to the development of an innovative idea or technology. Initially it was necessary to convince the users (i.e., UNOS and the medical/transplant profession) that the concept of an integrated, client-server-based information system, which only existed on paper, was a worthwhile endeavor given limited resources. The first step is always the toughest, because it requires an act of faith. Once initial approval was granted for developing *Xpedite*, it took almost a year before funds were available to construct a prototype.

Following the success of the prototype, and the lessons learned from it, the decision to develop a production version required a more intense round of justification that ultimately resulted in approval and financial support from the UNOS Board of Directors. The dual goals of improved communication and the reduction of organ wastage through better coordination were easy to justify and were widely supported throughout the transplant community. The challenge was to develop an approach that could accomplish these two broad goals. Because this was a new approach, it was necessary to build understanding and support for this effort continually with the Board of Directors and throughout the transplant community. Based on extensive feedback received from the transplant community, UNOS thought these efforts were successful.

What was not completely recognized was that the transplant community was largely unfamiliar with an information technology-supported communication environment. In other words, they were not familiar with the technology, particularly Lotus *Notes*. While it may be somewhat difficult to recall, in the early-to-mid 1990s the number of people with access even to e-mail was still relatively small. The limited experience with technology, especially one that was being increasingly integrated throughout the transplant process, may have created some discomfort with the technology leading to some reluctance or resistance to adopt and use it for job-critical tasks. Furthermore, the technology itself was somewhat limited. Even with the substantial advances in portability, laptop computers were still often less powerful than needed for some application environments. The more powerful machines were often cumbersome to handle physically, especially in already-cramped hospital environments like an operating room and intensive care facilities. Additional features, such as pen-based computing, were still in their operational infancy.

In addition, shortly after *Xpedite*'s launch, some turnover among the technical personnel and system champions began to occur at UNOS. Although qualified people remained with the organization and new hires were quickly placed, some momentum may have been lost as people moved into their new roles of support and product champion. As noted by Beath [1991], technology champions are often the most important single factor in the successful implementation of an information system. These champions are often transformational leaders [Burns, 1978] who are able to transcend hierarchy to steer the organization through a change process. It is likely that some prestige and status was lost since the new people, many of whom made lateral moves within the UNOS organization, were probably not as well known and, therefore, not as highly regarded by the Board of Directors and the larger transplant community.

Xpedite went through a typical adoption cycle, with supporters and detractors. Most agreed that better communications among the procurement coordinators and the transplant centers would benefit the organ placement and transplantation process. Early adopters of the system greatly appreciated the system. Others, some of whom may be described as technology-averse Luddites, did not want information technology intervention or support; i.e., the organ procurement and placement processes already functioned rather well. Some physicians were vocal supporters; others were not. For example, as *Xpedite* was more fully implemented, it was felt that the one-hour window for a transplant center to respond to a coordinator about an available organ could be reduced radically, thereby speeding the placement process. However, this potential change in policy would remove some of the control from the physicians, threatening their autonomy. As suggested in the job design literature [cf. Hackman and Oldham, 1980], autonomy is

> *"the degree to which the job provides substantial freedom, independence, and discretion to the individual in scheduling work and in determining procedures to be used in carrying it out"* [Hackman and Oldham, 1976, p. 257].

Further, research results show that physicians may be reluctant to react positively to information technology that interferes with or alters their traditional routines and medical practice [Anderson, 1997; Andersen and Aydin, 1997; Chau and Hu, 2002; Zetka, 2003]. Therefore, physicians may have been disinclined to adopt the new technology since they had little to directly gain from its implementation. Issues related to autonomy and control are also associated with the concept of power, which is discussed later in this section.

TECHNOLOGY EVOLUTION

Xpedite's design was the ambitious and complex melding of several independent technologies, specifically Lotus *Notes*, facsimile machines, and paging, with the already-existing IT infrastructure at UNOS. Further, the software in the IT infrastructure consisted largely of stand-alone programs. All were reliable technologies, yet they were maturing at different rates, and were not integrated, providing some potential instability for the organ procurement environment. For example, in 1995, IBM announced the acquisition of Lotus Development Corporation, the parent company of Lotus *Notes*. *Notes* was already a well-regarded and versatile communication environment. While IBM indicated that they would continue to support *Notes*, there were early signals that led to some uncertainty about which parts of the *Notes* environment would continue to be supported, which features would continue to be developed or extended, and how the technology support and fee structure environment would evolve under the new corporate parent. This uncertainty, and the lack of integration with the three communication technologies, made the environment more difficult to support and maintain.

These issues raised enough uncertainty about the long-term viability and stability of the *Notes* environment that consideration of an alternative approach was revisited. Recall that the procurement and placement process is a round-the-clock activity [Bruno, 1998]. Any disruption in the technology support infrastructure could cripple the process and might cost some people their chance at a longer, healthier, more productive life. Fundamentally, the system was technically very advanced in trying to coordinate the capture and exchange of information through Lotus Notes, facsimile, and pagers. Unfortunately, its leading edge technical superiority left the system difficult to support and maintain, ultimately making it untenable to continue, given the low adoption rate. But additional subtle reasons remain for the low adoption rate for *Xpedite*.

ORGANIZATIONAL COUPLING

UNOS and the transplant community are not a single organization. Instead, the transplant community is a group or network of mostly autonomous organizations that interact during the transplantation process. In the mid-1990s, the transplant community was a network of over 400 separate organizations, including UNOS, the organ procurement organizations, and the multitude of transplant programs around the United States. UNOS acts as a central point of coordination and communication in maintaining the list of potential recipients and the Scientific Registry of Transplant Recipients that listed who had received one or more transplants). However, although it monitors transplant-related activities to ensure compliance with transplant community guidelines, UNOS has little to no authority to control the actions and operations of other organizations within the transplant community other than through the coordination policies and procedures in place.

Thompson [1967] illustrated a conceptual scheme to describe the interdependencies among parts of an organization. These interdependencies, or the type of coupling, represent how work "flows" through the organization. "Pooled" coupling is where the various parts of the organization share resources, but are largely independent of one another. This state can also be characterized as loose coupling and is the lowest level of interdependency. In "sequential" coupling the organization members work in sequence or a series, where the work of one leads to another, then to another, and so on, as in a relay race. The interdependencies here are increased, i.e., tight coupling, for removing one member from the sequence will disrupt or disable the workflow. "Reciprocal" coupling is where organizational members receive inputs from and provide outputs to each other in a cyclical fashion. In this form of tight coupling, interdependencies are at their highest for a change that alters the flow of work both before and after the disruption.

In general, the transplant community might best be described as a loosely coupled network. The members of the transplantation network do not interact unless they are exchanging information with one another and one or more organs are subsequently placed for transplant. Much of the research on coupling in organizations is focused on control systems within a defined organization, where the “normative structure is only loosely coupled with the behavioral structure” [Scott, 1987, p. 81] or on the relationships among work groups or departments. The benefit of loose coupling is that the elements within the system are capable of relatively autonomous [Ashby, 1968; Glassman, 1973] and adaptive [Weick, 1976; Pfeffer and Salancik, 1978] behaviors or actions. Based on the work of Cyert and March [1963], Pfeffer and Salancik [1978] describe an organization as “a coalition of groups and interests, each attempting to obtain something from the collectivity by interacting with other, and each with its own preferences and objectives” (p. 36). Further, these coalitions evolve as new interests require different purposes and domains.

Yet, the organizations within the transplant community are also tightly coupled, at least at times. When a donor organ or multiple organs become(s) available, quick and accurate coordination is required to successfully place as many organs as possible with those awaiting a transplant. This coordination converts the loosely coupled environment into a very tightly coupled, sequential environment [Thompson, 1967]. On the macro time scale, reciprocal coupling exists as organizations contribute organs to and receive organs from the larger network for transplantation. Once a transplant is completed, the tightly coupled interdependencies between the different agents effectively revert to a loosely coupled environment.

POWER

Power, or more specifically a redistribution of power, may have been a contributing factor in the limited success of *Xpedite*. Emerson [1962] described power as the control over resources valued by others, and Berle [1969] notes that power resides in individuals, particularly where technical competence is important (Blau, 1955). Markus [1983] suggested that even in healthy organizations, resistance could be an important indicator that signals an information system may be altering the balance of power. In addition, Markus [1983] notes that although people and subunits within an organization will differ on their active efforts to gain power, it is doubtful that they will freely give it up.

The IT department within UNOS may be described as functioning in a fashion similar to the ‘technostructure’ delineated by Mintzberg [1979]. In Mintzberg’s view, the technostructure may design, plan, change, and train the people in the operating workflow, but they do not do the primary work of the organization themselves. The technostructure affects standardization and coordination in operations as suggested in the identification of technology and information technology as being a support activity in the value chain of an organization [Porter, 1985; Porter and Millar, 1985]. These changes are most effective when they can make the work of others effective in fulfilling organizational operations. However, even if unintended, some may perceive this support as a form of control or a reduction in autonomy, even if that is not the intent [Pfeffer, 1981]. If those affected perceive these behaviors as a form of control or as a reduction in autonomy, the users may resist. The extension of the IT infrastructure, and the resulting standardization of the organ procurement and placement process, may have threatened the power of the physicians and surgeons by shifting some of the expertise and control away from the physicians.

ORGANIZATIONAL INERTIA

An additional obstacle may have been the new and unique nature of the system. *Xpedite* was the first system of its type within the organ transplantation field and even in the larger general medical community. Before its development, organ sharing and placement was essentially the same for the more than ten years since the passage of the *National Organ Transplant Act* (NOTA) in 1984, and these operational processes were built largely on the informal exchange relationships that evolved in the earliest years of organ transplantation. Between the passage of *NOTA* and 1995, the number of transplants more than doubled. The number of interacting organizations increased to well over 400. To succeed in this complex, time-sensitive environment, routines needed to be developed [March and Simon, 1958; Pentland and Rueter, 1994]. Organizational change can be beneficial when it builds on established routines and competencies, but can be hazardous if found to be too disruptive to normal routines [Amburgey, Kelly, and Barnett, 1993; Haveman, 1992]. Even positive changes can have disruptive consequences as old routines need to be discarded or evolve. Fundamentally, the tendency of an organization, and individuals, is to resist change and maintain the status quo.

It is not clear from the information available, but it appears that the limited familiarity with the technology, the potential for significant disruption of normal operations, and the change in power structures may have contributed to *Xpedite*'s lack of adoption.

V. EPILOG

While many of the issues identified in this articled remain incompletely resolved, UNOS continued to function. The Organ Procurement and Transplantation Network, including *Xpedite*, was named one of the ten most successful computer systems in the federal government between 1987 and 1997, receiving the Monticello Award [Jones, 1998; Rayner, 1998]. In addition, UNOS was nominated in the medicine category for a 1998 *Computerworl*d Smithsonian Award for the advanced and innovative use of IT [Rayner, 1998).

Xpedite's operations were terminated on December 15, 1997. However, almost all of the features implemented in or envisioned for *Xpedite* are now incorporated in the Internet-based successors. UNOS early on recognized the potential of the Internet for providing information, creating its first web site in 1995. However, like many organizations, recognition of the greater opportunity to leverage the capabilities of the Internet came a bit more slowly. As attention shifted away from *Xpedite* the realization grew that migration to the Internet offered the chance to develop an improved platform to support organ procurement and placement. By moving to the Internet, UNOS found an environment for system development that was less expensive to maintain, relatively easy to upgrade or enhance the software, and both reliable and robust enough to support the 24/7/365 operational demands of the transplant community.

TRANSITION TO THE INTERNET

Migration to the Internet for organ donor and recipient data collection and matching solved several of the challenges faced with *Xpedite*.

1. The Internet is largely platform independent, especially after Netscape *Navigator* and Microsoft's *Internet Explorer* browsers were developed.

2. The open, largely nonproprietary, protocol-based architecture of the Internet made it much easier to design, develop, and maintain the software necessary to perform UNOS' functions. As a result, no new hardware or software was required to interface with UNOS' *Match* system.

3. The browsers were relatively easy to use, overcoming at least some of the resistance or reluctance to use the technology. In addition, physicians and other medical personnel were becoming increasingly familiar with IT and more aware of and comfortable with how it could support their medical work.

4. The basic concept of the Internet as a loosely coupled network of interconnected computers may be compatible with the tacit mental model of the users.

5. The transplant community was becoming increasingly familiar with IT support through their exposure to *Xpedite*. The looming Internet boom of the late 1990s also pulled many late adopters into the Internet environment. The Internet itself, being a network of interconnected computers, provided a reliable and robust infrastructure for consistent, stable communication throughout the

transplant community. Organizations within the transplantation system still were required to connect to the Internet, either through a dial-up phone line or by becoming a more permanent node on the network. In general, connectivity was relatively easy and inexpensive.

Some of the organizational issues continue to evolve. The cadaveric donor base did not grown much in the 20 years since the passage of *NOTA*, although medical technology allowed an increase in the use of living donors to fill at least part of this growing deficit [UNOS, 2001]. Unfortunately, the demand for transplants continued to grow, with over 92,000 currently on the waiting list [UNOS, 2004].

Xpedite, and its successors *UNET* and *TIEDI* (the *Transplant Information Electronic Data Interchange*) helped reduce some organ wastage and improved the capture and communication of donor and recipient data. Both were designed with the input of advisory committees made up of system users. *UNET* is a private, password-protected secure Internet site that integrates the patient waiting list, organ match runs and placement, and transplant data capture. *TIEDI*, one of the component pieces of *UNET*, uses the concept of electronic data interchange (EDI) as a guiding framework. It is a more user-friendly interface for the capture of donor and recipient data. It provides better links for matches to the Waiting List and greater accuracy for transplant data transfer to the Scientific Registry of Transplant Recipients.

Recall that in addition to the actual match and transplant, this data ultimately is placed in the Scientific Registry of Transplant Recipients. Mining this data allowed the transplantation scientists to broaden the parameters (e.g., age) of acceptable donors, thereby enlarging the pool of available organs somewhat. New advances in medical science also made it possible for living donors to contribute kidneys and grafts of partial livers and lungs for transplantation [UNOS, 2004]. Constant mining and analysis of the data also led to new policies and criteria for allocation and placement of some needed organs where the wait time for transplantation was excessive for some people [cf. Johannes, 2004; Koch, 1999; Pritsker, 1998]. These new policies continued to try to balance donor availability with the demands of potential recipients and transplant facility capabilities and needs.

V. CONCLUSION

Organ transplantation is still a relatively young domain of medical practice. The entire domain — from organ procurement and placement, to donor-recipient matching, to patient maintenance following transplantation — requires constant observation and assessment for ways to improve and refine the transplantation process. *Xpedite* was developed using the RAD methodology to facilitate rapid, low-cost development of a high-quality system to improve organ placement and to better integrate the IT infrastructure. It was a client/server environment designed to resemble the operations and functionality of sales force automation. *Xpedite* leveraged human capability by improving communication of data and coordination of the procurement process through the use of information technology, allowing the organ procurement coordinator to concentrate on donor management. This required extensive human interaction (among donor family members and medical personnel), while the system handled communications and dissemination of donor information.

However, for a variety of technical and organizational issues, Xpedite never completely achieved the goals set for it. Operations for *Xpedite* were terminated only 24 months after activation. Although performance goals were achieved, it was technically too complex and expensive to maintain, especially given the low adoption rate in the transplant community. As *Xpedite* was terminated, a better approach in terms of cost, support, and user accessibility was found to be available through the Internet, and that transition was implemented rapidly.

Challenges from the transplant community were encountered and addressed*.* *Xpedite* may have challenged the status quo in the decision making process, creating some resistance to its implementation. In addition, it was not implemented across all relevant operating platforms, meaning that some organizations would be required to transition or upgrade to the platform supported from their existing hardware and software systems. These conflicts were ultimately resolved as UNOS migrated to an Internet-based environment.

UNOS learned from the experience that they may be the technical core of the diverse transplant community, but that the community members' needs are not uniform. The transplant community looks to UNOS for a consistent, reliable infrastructure to support transplantation operations, but may resist other perceived changes. In an era when organizations are increasingly interconnected, technology is increasingly embedded in both internal and inter-organizational operations, and organizational goals among related organizations may not always be in congruence, the concepts presented in this paper raise provocative questions that require further investigation.

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ABOUT THE AUTHORS

Jon W. Beard is Visiting Associate Professor in the Krannert School of Management at Purdue University. His research interests are in the areas of the strategic implications of information technology, information architecture, the impact of technology change on an aging population, and on the individual and organizational effects of workspace design. His articles appear in a number of including the *Journal of Strategic Information Systems*; *Research in Organizational Change and Development; Knowledge, Technology, and Policy; Organization Development Journal;* and *Journal of Information Systems Education*, among others. He is the Editor of *Impression Management and Information Technology* (Quorum, 1996) and *Managing Impressions with Information Technology* (Praeger, 2004).

Berkeley M. Keck is the Assistant Executive Director for Information Technology and CIO for the United Network for Organ Sharing in Richmond, VA. As CIO he is responsible for all aspects of information technology, including network/hardware operations, database operations, planning/development of all application systems, and the UNOS organ center. He joined UNOS in 1992, becoming Director of IT in 1996. He has worked as a nurse, nurse instructor, nurse clinician, and director of nursing. He was a Captain in the U.S. Army Nurse Corps. His research interests include cardiac transplantation. He was the primary author of a chapter on thoracic transplantation in *Clinical Transplants for 1994 – 2000*.

Tim O. Peterson is Associate Professor of Business and Director of Undergraduate Learning Assurance at Texas A&M University. He teaches management, organizational behavior, work life competencies, and leadership. His research interests are leadership, work life competencies, the scholarship of teaching, and the application of information technology to organizational issues. His papers appear in the *Academy of Management Education and Learning*, *Academy of Management Executive*, *Performance Improvement Quarterly*, *Journal of Leadership Studies*, *Journal of Management Education*, and *Journal of Management Systems*.

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