MEMORANDUM

TO: MASSACHUSETTS GENERAL HOSPITAL MANAGEMENT

CC: PROFESSOR PALLEY

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SUBJECT: SYSTEMS ANALYSIS AND DESIGN PROJECT: PHASE 3

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Executive Summary

Before choosing a model for the CABG Care Path Information System, two alternative designs were considered. These are referred to as the station-based and wireless-networked alternatives. In the station-based model, a limited number of users access the system via computer terminals at designated locations throughout the hospital. These stations are networked to a central database. The database application, designed in Microsoft Access, must be installed on each of these terminals. The wireless-networked alternative is a high-end solution. In this design, a wireless network is established in the hospital. A larger number of users access the system primarily through PDAs. The database processing would be executed using Oracle, while the user interface would be web-based.

After comprehensive analysis of the alternatives, the **wireless-networked solution was recommended** for a number of reasons. First, in terms of technological feasibility, the wireless-networked alternative allows for user mobility, is equipped with more advanced database software, and is easier to upgrade. Second, with regard to organizational feasibility, the implementation of the wireless-networked solution would cause less disruption to the hospital, require less physical space, and increase the speed of information flow between various caregivers along the care path. Finally, the economic feasibility analysis demonstrates that if the wireless-networked system decreases patient stays by just a few more hours than the station-based alternative, it would justify its additional cost. We believe that this scenario is highly likely.

Overview of the CABG Care Path System

Coronary Artery Bypass Graft Surgery (CABG), more commonly known as bypass surgery, is among the many types of surgery performed at Massachusetts General Hospital. A standard CABG procedure consists of three main phases: preoperative testing, surgery, and recovery. Originally, the entire process involved a patient hospital stay of approximately 6-14 days. Due to the length of and large variability associated with the patient's hospital stay, a great deal of uncertainty surrounded the extent to which MGH's resources would be used during each patient's procedure. In an attempt to standardize the procedure and reduce hospital costs, an effort was undertaken to create a CABG care path. The care path annotated in detail the goals and events associated with each phase of the surgery, from hospital admittance to discharge. In this way, the care path created a clear standard for each sub-process of the CABG procedure.

The implementation of a CABG care path did not introduce new treatment technologies or significantly change the operating procedure. Instead, it attempted to standardize procedures, shorten the patient's hospital stay, and reduce the variability between the various surgeons' performances. Although no specific changes were made to the operating procedure, the care path did require changes in many processes and practices across departments. The users of the system have a greater need to be well integrated and in close communication. The care path was implemented as a paper checklist. The inputs are checks to be placed on various steps of the worksheet as the patient moves along the path. The current care path at MGH requires nurses to document each step by hand. A care path check sheet is maintained in addition to normal

and extensive records for each patient. Once the patient reaches the end of the path, each completed checklist remains in hard copy form in the patient's file.

Organizational Problems and Goals for the New System

The care path system was created in response to a few major problems: variability in hospital procedures and high costs. While implementation of the care path created substantial progress in addressing these problems, even the biggest proponents of the system recognize the potential for improvement. Therefore, the goals of the new system represent a combination of the original goals of the care path and newly defined goals related to its improvement. The following table lists the goals of the organization related to the new system:

Problems	Goals
Large variability in how the CABG procedure is performed	**Standardizing the operating procedure**
Relatively high length of stay and costs as compared to other hospitals	**Detecting diversions from the care path and alerting caregivers. Producing exception reports for analysis**
Poor cost accounting and no centralized documentation	**Improving record keeping for better patient records and cost analysis**
Poor communication between parties along the care path	**Improving the communication between various parties within the care path system**

Minimum Requirements for New System

In designing the new system, a reasonable alternative must possess the following qualities:

Hardware	• High-Speed Server • Network • "Terminals" For User Access
Software	• Database Software with Query and Report-building capabilities
Number of Users	• Access for approximately 75 potential users • Nurses • Care Path Doctors • Cardiac Surgeons (8 in total)
Volume of "In Progress" Patients	• Approximately 30 "in progress" patients • Simultaneous system access by different users. • Simultaneous updating capabilities.

Hardware

In order for a system alternative to function, there must be a database of care path patient information. Constant reference to this database will be needed to access procedural information or to attain information about a particular patient. In addition, a network must be established where all users can access this information from locations within the hospital. This network of "terminals", along with a central, standardized database, will allow for easy accessibility of information for all caregivers throughout the path.

Software

Database software will be used to manage the content and flow of information for the Care Path system. This software must be capable of querying the records so individual pieces of information can be accessed for analysis purposes. In addition, the software must be able to produce documents such as exception

reports, cost accounting reports, and utilization reports. Such features are necessary in order for the system to add value for Mass General Hospital. Finally, since medical records are confidential, the system must be secure and ensure the integrity of the data.

Number of Users
At a minimum, the users of the new system will be the 8 cardiac surgeons, team of cardiologists, and nurses that are working along the care path. These are the primary and most active caregivers in the care path system. While system access for additional users such as support staff, physical therapists, and specialist doctors is an added benefit, it is not an absolute necessity.

Volume of Transactions
According to the MGH website, the hospital performs approximately 1000 CABG procedures per year. Using this figure, a safe estimate of the number of possible patients in the system at any given moment is 30. The new system must be capable of monitoring 30 patients active on the care path. In addition, the system must be able to seamlessly update the records of several patients simultaneously.

Alternatives Considered

The two main alternatives under consideration will be referred to as the station-based and wireless-networked solutions. The differences between these alternatives stem mainly from the way in which users access the system.

Station-Based System
In the station-based alternative, users access the system via computer terminals. These terminals would be located at nurse's stations, surgeons' offices or surgeon lounge, and in the care path administrator's office. At each step in the care path, nurses would enter relevant data into the system. Doctors could access the information from any of the terminals or request printouts to be delivered by nurses.

The terminals would be connected to a new server via a LAN network. The station-based system uses Microsoft Access instead of the higher priced Oracle software application. The Access database would be able to be queried to extract desired parcels of information. In addition, exception, utilization, and cost analysis reports will be available. This cost saving strategy thus provides similar features but with a slower execution time. Looking at the available technology, Access is definitely not comparable to Oracle in terms of efficiency and execution time. Although the system would allow secure access for the approximately 75 potential users (cardiac surgeons, cardiologists, and nurses), the number of simultaneous users would be limited by the number of available terminal stations.

Wireless-Networked System
In the wireless-networked alternative, users access the system via hand-held PDAs. If users already have PDAs there will be upgrades available. A wireless network would be established throughout the hospital complex allowing users from many different parts of the care path to access the system. The wireless network would be connected to a new Dell server that is in turn connected to the ground-based LAN. A limited number of desktop stations would also be available for users to access the system. These terminals would be located at select nurse's stations and would have report-printing capabilities.

The number of users this system would support exceeds the minimum requirements. Technicians, social workers, and select support staff at the hospital would also gain access.

Unlike the station-based system, Oracle database software would execute the data queries and produce the desired reports. Oracle was chosen as part of this high-end alternative because of its brand name, reliability, intense customer software support, and excellent security features. The front-end system would be a web-based interface easily accessible from the PDAs and terminals. The number of simultaneous

users of the wireless network would theoretically be very high. It would only be limited by network congestion.

A summary description of these two alternatives is provided below:

	Station-Based	Wireless-Networked
Users Access the System via:	• 20 Computer Terminals at nurses' stations	• Hand-held PDA's
"Terminals" Connected to Server via:	• T-1 Connection	• Wireless Network
Scope of System Users:	• Nurses, Doctors, Care Path Administrator	• Nurses, Doctors, Care Path Administrator, Therapists, Pharmacists, Selected Support Staff
Maximum Number of Simultaneous Users:	• 20	• Very High. Limited only by network capacity.
Hardware Required	• 20 PC's • 20 Ethernet Cards • Dell Poweredge 6650 Server • 1000ft CAT5 Cables	• 100 PDA's • 1 Dell Poweredge 6650 Server with Oracle • 20 Cisco Aironet Access Points • 100 PC Cards • 2 Cisco Aironet 350 Wireless Bridges
Software Required	• Microsoft Access	• Oracle Database Software (comes with server)
Application Developed by:	• External Consultants	• External Consultants
CABG Care Path Application: Front End	• Access	• Web-Based

Feasibility Analysis

To properly evaluate the positive and negative attributes of the station-based and wireless- networked systems, it is imperative to conduct an analysis that evaluates the technological, organizational, and economic feasibility of each alternative. By systematically assessing each component, the most appropriate system choice can be identified.

Prior to delving into the pros and cons of the two alternatives, it is important to note that the alternatives share certain common traits. First, in terms of hardware and software availability and affordability, MGH can easily implement either solution. In addition, station-based and wireless technologies are constantly evolving, providing assurance that the hospital will have long term capabilities for upgrades and maintenance. Next, data conversion difficulty is a mutual issue. Currently, patient information is stored in paper files, with hand-written charts and diagnoses. Transferring the data into a database is labor and time intensive. Transcription costs will be considerable in the short term. However, as previously discussed, the long-term benefits of either system will compensate for these near-term expenses.

Technological Feasibility

Hardware

A further look at the hardware shows clear distinctions between the alternatives. PDAs present three clear disadvantages. First, PDAs have a limited battery life. Users will have to be aware of battery levels during their shifts and make sure to charge the devices when necessary. Apart from adding a new responsibility to the busy hospital staff, if nurses plan to use PDAs around the clock, then extras must be available. Second, since wireless networks operate on radio frequencies, they can be intercepted by eavesdroppers. Patient

information is extremely confidential and breaches in security would tarnish the reputation of the hospital. Therefore, instituting additional protective measures is an added cost of the wireless-networked solution. Lastly, PDAs are small in size, making them easy to lose.

The upside of wireless networks is that they allow for user mobility. Doctors and nurses have real-time access to all information in the database. This function saves time because users do not have to go to the nearest terminal each time they require data access. While wireless networks have a limited range, the hardware will allow the PDAs to function throughout the hospital. Likewise, if a doctor wants to take data home, he can take the PDA, which while being out of range for updates, still retains all previously streamed data. The user mobility afforded by wireless systems adds to overall productivity.

Application Software

Since the station-based network uses Access and the wireless network uses Oracle, there are fundamental differences in how the two will function. The main advantage of Access is the familiarity of users with the application. Oracle uses SQL language, requiring the construction of a web-based front end to simplify use. In terms of the software's capabilities, Oracle stands above the rest. Oracle provides the user with various functions and flexibility, reliability, heightened security, fast querying and constant upgrades. Meanwhile, Microsoft Access compares poorly to Oracle and is more suitable for smaller sets of data. When encountered with large queries, Access tends to take a long time and pose the threat of crashing.

Keeping up with the Future

Medical technologies and procedures are constantly evolving. Therefore, a vital requirement is the ability to adjust the system according to changes in the CABG care path. Upgrades and changes are easier and timelier with the wireless-networked alternative. Since the system is web-based, the database administrator merely has to load information onto the central server. Consequently, the network can be easily configured and rearranged to accommodate a variety of settings. Updating the station-based system requires more work because the administrator must load software onto the network through the server and then go to each terminal to reconfigure the application. Also, addition and replacement of terminals is more costly with PCs. A new PC costs around $2000 in comparison to $500 for a new PDA. Thus, while upgrades and expansions might be desirable in the future, additional costs and interference associated with a station-based network could dissuade the hospital.

Integration with the Existing System

An optimal network should not only not interfere with existing systems but also aim for interoperability. Wireless networks provide an advantage by automatically linking doctors and nurses to other resources. When a patient leaves surgery and is taken to the ICU, a nurse must first go through administration to check in. This task can be circumvented by using the PDA to send a direct feed. Similarly, a prescription can be instantaneously processed by the hospital pharmacy and be ready as soon as the patient arrives in recovery.[1] In contrast, the time taken to access, log-onto, and enter data into a PC would take even longer than personally delivering the request.

Organizational Feasibility

Infrastructure Adjustment

In implementing the alternatives, possible infrastructure changes must be evaluated. In order to set up a land network, MGH has to lay down wiring in the walls and ceiling. Apart from the costs incurred by hiring electrical contractors and purchasing the hardware, the construction will disrupt daily activities at the hospital, temporarily decreasing the quality of care. Areas of the hospital may need to be provisionally

[1] Nelson, Matthew G., *Doctors Trade in Clipboards for PDAs*, http://www.informationweek.com/story/IWK20010726S0024.

closed off due to construction. Moreover, since CABG procedures require finely calibrated machinery, re-wiring creates a risk of interference. These effects would be minimized if the wireless-networked solution were chosen. A related issue that has received much recent medical attention is the effect the electromagnetic waves associated with wireless networks have on sensitive machinery. However, studies have shown that new PDAs are built with low power transmitters that prevent electromagnetic interference. In addition, neither the FDA nor FCC has found grounds to ban wireless devices in hospitals[2], allowing many to upgrade to wireless systems.[3] Thus, the construction stemming from installing a station-based network is more likely to cause interference with existing infrastructure.

Spacing Requirements

The station-based system causes a larger space infringement than the wireless network. Setting up the wireless network is easy and only entails finding room for the server, Aironet access points, and wireless bridges. In contrast, the station-based network necessitates room for each PC. Since space is a valuable commodity at MGH, it is more efficient to use it to increase capacity. Fewer wires and connectors also lead to increased reliability since there are fewer components liable to break.

Speed of Information Flow

A key advantage of the wireless network is the speed of information flow. One of the central objectives of the care path is shortening the patient's stay. PDAs save users the time of having to go to a terminal, archive through the data and make printouts. The constant feed of data ensures that live updates and upgrades do not interfere with scheduling. In addition, providing a doctor constant access to charts and data could save each doctor up to an hour per day. This increases the throughput of the system and saves costs.

New Demands on Users

Both alternatives redefine user expectations and involvement. Especially with the wireless system, doctors and nurses must make adjustments to their routines. Normally, data is noted during the course of the day but not officially filed until the end of the shift. A wireless system forces users to enter data as it comes in, while PCs can be updated periodically. Consequently, a problem with station-based networks is the possibility of redundancy since users might continue their routines by taking notes throughout the shift.

Importance of Training

The availability of technical expertise plays an integral role. Many nurses are familiar with the use of a PC and would require limited training to become acquainted with a station-based system. On the other hand, knowledge of PDAs is limited, forcing the hospital to devote time and resources to training users about the hardware and software. Given employees busy schedules, training sessions will infringe on the number of doctors and nurses available. Also, specialists must be brought in to help with the training in nascent stages.

Prestigious Technology for a Prestigious Hospital

Finally, MGH is considered one of the most prestigious hospitals in the United States. It has been a leader in healthcare for decades, and through its affiliation with Harvard is developing the new generation of doctors. This prestige gives it the right to be a technological leader in healthcare. Since wireless technology is the new phenomenon, MGH should be at the forefront of its adoption.

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[2] Gilfor, Jeff, *Wireless Devices and Electromagnetic Interference in Hospitals, Urban Myth?,* http://www.pdamd.com/features/interference.xml.

[3] Emerson, Dan, *Hospitals Wheel in Wireless Future,* http://www.bizjournals.com/twincities/stories/1999/03/08/focus2.html.

Economic Feasibility

The wireless-networked alternative requires a higher initial investment than the station-based alternative. This is due primarily to more expensive hardware and a more complex software application. In the base case, (Appendix A), the station-based system has a quicker payback than the wireless-networked system by about a half year. In addition, the station-based alternative has a slightly higher NPV. If interest rates were to rise from 3% in the base case to 7% (Appendix B), both NPV's decrease. In addition, the NPV of the station-based alternative would still exceed that of the wireless-networked. The next scenario uses a higher growth rate for CABG procedures performed per year at MGH (Appendix C). In this case, the NPV's for both alternatives are considerably higher and the payback time is slightly shorter. However, as in the previous two cases, the station-based alternative still outperforms the wireless-networked under these assumptions. The final scenario analyzes what would happen if the implementation of the wireless-networked alternative were to reduce patient-days by a slightly greater amount than the station-based solution (Appendix D). As described earlier, there are some technological and organizational feasibility issues that may produce this result. In this case, the extra slight decrease in bed-days causes the NPV of the wireless-networked system to exceed that of the station-based system. In this way, the conclusions drawn from our economic feasibility analysis are *extremely sensitive* to the potential cost reduction benefits associated with shorter hospital stays for patients. Thus, there is no clear-cut winner in this respect.

Recommendation and Conclusions

Feasibility Analysis Results

	Station-Based	Wireless-Networked
Technological Feasibility		☑
Availability of Network Components	☑	☑
Data Conversion	☑	☑
Hardware Application		☑
Software Application		☑
Flexibility/Upgradability		☑
Interoperability		☑
Organizational Feasibility		☑
Infrastructure Adjustment		☑
Spacing Requirements		☑
Processing Speed		☑
New Demands on Users	☑	
Training	☑	
Prestige		☑
Economic Feasibility	☑	☑

The feasibility analysis of the station-based and wireless-networked solutions has revealed appealing attributes and deficiencies in both alternatives. However, the wireless-networked alternative has some key advantages. First, greater user mobility has the potential to increase productivity of the caregivers and decrease hospital costs. In addition, the system software is more powerful and can be updated more easily. Finally, the implementation of the wireless-networked system would cause less disruption to hospital operations. All things considered, given the current goals and future expectations for the care path system, the wireless network is a more optimal solution for MGH.

Team Leader's Report

All members of the team worked extremely hard on Phase III and made substantial contributions. All team members were present at all meetings. The following is an outline of each member's responsibilities:

Mikhail Katz	Technological and Organizational Feasibility, Recommendation
Hila Kollnesher	Minimum Requirements, Alternatives Considered
Aaron Rosen – Team Leader	Alternatives Considered, Economic Feasibility, Executive Summary