Evaluating Alternative Methods of Providing Database Access over Low Speed Communications

by

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EVALUATING ALTERNATIVE METHODS OF PROVIDING DATABASE ACCESS OVER LOW SPEED COMMUNICATIONS

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(ABSTRACT)

One of the most important activities in the systems engineering process is the determination of the best implementation method from a set of alternatives. This project describes a process that can be followed to evaluate a set of implementation alternatives. This process consists of performing the following activities: Definition of the need, requirements and functional analysis, evaluation of the alternatives, requirements validation, and risk identification. To clarify the activities in the evaluation process, the project follows a case study in which the XYZ Corporation determines the best implementation approach for providing access to a remote database over low speed communications lines.

Three alternatives were evaluated by the XYZ Corporation. After performing the evaluation, an HTML only implementation approach was selected. This
implementation had the highest performance and dependability compared to
the other alternatives. Regional users will use a Netscape browser to view
HTML pages stored at the corporate headquarters. A web server located at
the corporate headquarters will interface with the database server by
performing the required additions, updates, and queries to the corporate
database. The web server will also format the returns into HTML pages for
viewing at the regional sites.
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1 Introduction

1.1 Project Introduction

One of the most important activities in the systems engineering process is to choose an implementation approach from a variety of options. Before design of the system can occur, it is necessary to choose the implementation approach that will satisfy the stated need. This project is an example of a process that can be used to ensure that the best approach is chosen.

The XYZ Corporation produces a variety of widgets and gizmos for customers located around the world. The Corporation is organized with its headquarters located in Washington, DC and regional sites located in Orlando, San Francisco, Chicago, London, Tokyo, and Berlin. Most widgets and gizmos are produced at the corporate headquarters, but the regional sites also have the capability of producing simpler products. Each site maintains inventories of popular widgets and gizmos for use in the surrounding region.

The XYZ Corporation needs to provide its regional users access to the corporate database over slow communications lines. The purpose of this
project is to follow a process to determine the best implementation method for connecting the regional sites to the corporate database. To determine the optimum implementation, the following activities need to be performed:

- Definition of the need,
- Requirements analysis,
- Functional analysis,
- Evaluation of alternatives,
- Requirements validation, and
- Risk identification.

1.2 Background on Corporate Database

The corporate database was developed for two purposes. First, the database provides a mechanism for tracking work orders. All groups in the corporation create work orders to track their activities. For example, if a user requires a new widget, the widget production department will open a work order. This work order can be used to track information such as the labor and parts required to produce the widget. Second, if creation of the widget requires production of another component by a different group, the widget production
department can open a child work order. This child work order will task a separate group to produce the required component for the widget.

Additionally, the database provides a tracking mechanism for inventories. A user can easily perform a query of the database to determine information such as which piece of equipment to use to perform a specified function. Other searches of the database allow a user to determine where the closest instance of a specific widget or gizmo is located.

1.3 Statement of Need

The corporate database provides a tracking mechanism for work orders and inventories. The objectives of developing the corporate database were to increase the ability to distribute information about work orders and inventory to all the XYZ users dispersed around the world. Additionally, the corporate database was developed to reduce the size of the XYZ work force performing manual tasks of data entry and searches for information pertaining to specific work orders and inventory. In order for the corporation to fully realize the benefits of automating the work order and inventory tracking capabilities, all sites must be connected to the database. Connectivity to the database
includes the ability to add and update information in the database and also to receive information from the database.

The users in the headquarters building were connected to the corporate database on February 1, 1996. The corporate database is currently using Microsoft SQL Server as the database server. Users in the corporate headquarters use a Microsoft Access application as the front end client application. Direct connectivity to the database in the headquarters was achieved first for many reasons, including the significantly greater number of users and transactions in the headquarters and the limited bandwidth available to the regional sites.

The true advantages of automating the tracking processes provided by the corporate database will not be realized until the regional users have direct connectivity to the database. In order for the database to track the corporate information, it is necessary for information from the regional sites to be entered into the database. However, because the regional sites do not have direct connectivity to the database, employees at the corporate headquarters are forced to manually enter data from the regional sites into the database. Additionally, when the regional users require information that is stored in the
database, employees at the corporate headquarters must perform the database searches for the regional employees. By providing direct access to the database for the regional users, significant savings can be accomplished by redistributing the work force that is performing the manual processes for the field. The activities that these employees perform are direct copies of the processes that are being performed in the field. Providing the direct access to the database will reduce the need for dual entry that is bloating the data entry work force.

The corporate database provides inventory tracking for the entire corporation, not just the headquarters users. Regional sites also have the capability of producing new products, distributing existing products, and requesting products from other sites, including the headquarters. To facilitate these activities, the client application used at the regional sites must allow users to at a minimum:

- Create new products for tracking
- Track the location of products
- Place orders for products
- Find the closest location of a specified product
- Create work orders
- Update work order status

To perform these functions, the regional users must add, update, and query the corporate database.

All sites in the XYZ corporation work the same. All information will be stored in a database centrally located at the corporate headquarters. No data is stored at the regional sites. This is possible because all of the sites deal with the same equipment and follow the same business rules for tracking work orders and inventory.

To facilitate the central tracking of work orders and inventory, the regional users in the field must add new data to and update the data in the central database. Employees at the corporate headquarters currently perform these functions for the regional users by reading faxes received from the regional sites. The activities recorded on the received fax are manually translated into additions and updates to the database. This is a time consuming and error prone operation. Providing a means for regional users to add and update the
database will improve the accuracy of the database by removing one process that allows errors to enter into the database.

The database will also help regional users work more efficiently by allowing the users to have direct access to the data that is stored. For example, the regional users will be able to quickly find the location of a piece of equipment through the use of the corporate database. To view information from the database, the regional users will send query data to the database server. They will then receive query reports for items matching their query request. Figure 1.1 shows the data that will flow between the regional sites and the headquarters. This is a much more efficient process than having employees at the corporate headquarters perform the query and relay the information to the users at the regional sites.
Figure 1.1 - Data Flow Between Headquarters and Regional Sites

Three things are needed in order to provide the regional users with access to the corporate database located at the headquarters: communications between the regional sites and the headquarters; a database server that is capable of handling remote requests; and a client application in the regional sites that is capable of interfacing with the corporate database. Currently, dedicated communications lines and the Microsoft SQL Server database are available to provide the regional sites with access to the corporate database. Figure 1.2 shows the communications topology of the system. All regional sites can
communicate with the corporate headquarters. Communication between regional sites only occurs by sharing data in the corporate database located at the headquarters. To complete the requirements for connectivity, the client application used for interfacing with the corporate database must be determined and developed. Development of the client application can begin on May 1, 1996.

![System Communication Topology](image)

**Figure 1.2 - System Communication Topology**

Figure 1.3 shows the communications architecture at and between the corporate headquarters and one regional site. The wide area communications
are provided by a dedicated leased 9.6 kilobits per second (kbps) point to point communications line to each site. A token ring network running at 16 megabits per second (Mbps) provides local communications in the corporate headquarters. Each regional site uses a 10 Mbps Ethernet local area network. All communications in the architecture use the TCP/IP protocol.

![Network Architecture Diagram]

**Figure 1.3 - Network Architecture**

The biggest obstacle to providing connectivity is the bandwidth of the communications lines between the regional sites and the corporate headquarters. When the project was started, the underlying assumption for
remote connectivity was that the bandwidth would be increased in the future. However, due to the communications infrastructure available in the foreign countries, the bandwidth to the regional sites has not been increased. This also makes it highly unlikely that the bandwidth will be increased in the future.

The lines between each regional site and the corporate headquarters are dedicated 9.6 kbps. In addition to network traffic, fax and voice transmissions are also multiplexed onto the lines. Figure 1.4 shows the connectivity of a regional site to the headquarters. Because of the varying load on the lines, the nominal available bandwidth for the database application may vary from the full 9.6 kbps to as little as 1.2 kbps.
Figure 1.4 - Connectivity Between Headquarters and a Regional Site

The XYZ Corporation will not allow dial up access to the corporate database. This decision is based on two factors: cost projections for paying international long distance charges, and threats of industrial espionage over unprotected phone lines. Therefore, it is not possible to use high speed modems over standard phone lines to provide faster communications to the corporate database.

To circumvent the lack of database access, the regional users write faxes describing their activities. These faxes are sent back to the headquarters.
where personnel are manually inputting the data into the database. This process is slow, inefficient, and error prone. Additionally, the faxes received from the regional sites do not always contain all of the information required to maintain the database. This requires headquarters employees to spend additional time communicating with the regional users to obtain all the required information.

In order to maintain the usefulness of the corporate database, it is necessary for the regional sites to have access to the corporate database. This will remove the dual entry of data from the regional sites and ensure that the data being entered accurately represents the regional activities. It will also allow the entire corporation to communicate through the work order process. To provide the regional sites access to the database, it is necessary to determine the best method for the regional user to use the database. The headquarters users are currently using a Microsoft Access application for accessing the database. However, for the regional sites a more efficient application designed specifically for access over limited bandwidth may be necessary.

The client application that will be used at the regional sites must provide adequate performance over the low bandwidth communications lines.
Adequate performance means that users will still be able to complete at least the same number of work orders as they currently do, approximately 20 work orders per day. Additionally, the application must provide dependable communications by not introducing any errors due to the communications lines into the database.

The XYZ Corporation determines yearly expenditures based on the fiscal calendar. In order to maintain funding for the corporate database project, the Information Systems Division must provide a working product for regional usage before October 1, 1996, the start of the fiscal year. Due to limited resources, it may not be possible to provide fully automated functionality to the regional sites before October 1, 1996.

The regional sites consider full functionality to include the ability to input their data into the database and view data that is stored in the database. Currently, data from the regional sites is being input manually into the database by employees at the corporate headquarters. Although this process is inefficient and error prone, the data from the regional sites does get entered into the database. In order to meet the requirements for achieving full functionality, the regional sites must have the ability to view the data being
stored in the database. If the regional sites are given viewing capability by October 1, 1996, the necessary funding will be available next year for implementation of remote entry of data into the corporate database.
2 Requirements Analysis

2.1 Operations Concept

2.1.1 Mission Definition

The field application will be used in a similar manner at every field location. The application will be started first thing in the morning when a user logs onto the local network. When started, the application will display all the work orders currently assigned to the user. The user can then use this knowledge to begin working on those assignments. The user will periodically refresh the display of assigned work orders throughout the day. It is not necessary for the application to automatically update the list of work orders assigned to a user. This is because business practice states that a user must be notified by phone that a work order is being tasked. This allows a user to state their current work load so that no one user is inadvertently over tasked.

Figure 2.1 shows a summary of a user's interaction with the work orders in the database. During the course of a normal workday, a user will perform...
work on the most pressing work orders. When work is completed, the work order must be updated to reflect completion. Periodically, it may be necessary for a work order to be re-assigned to a coworker. This may be necessary to take advantage of specialized knowledge or to redistribute work to employees with lighter work loads.

![Diagram of Work Order Processing]

**Figure 2.1 - Summary of Work Order Processing**

While working on one work order, a user may need to task a different group to perform an activity. This tasking is done through the creation of a new
work order, called a child work order. However, since completion of the first work order depends on the successful completion of the new work order, a parent/child hierarchy arises. The corporate database must allow for these parent/child relationships to exist between work orders. Figure 2.2 shows how a hierarchy of work orders can arise. When a child work order is opened, work is suspended on the parent work order. Activities on the parent work order will continue when the child work order is completed. These changes in the status of the parent work order must be reflected in the database. Users must have access to the child work orders when reviewing the parent. This allows a user to determine the status of the child work orders and get in touch with the individuals responsible for completion of the child work orders.
Figure 2.2 - Hierarchy of Work Orders

The user will also use the system for querying the database for information related to the widgets and gizmos. If the user does not know which widget or gizmo to use, the database can be queried to determine the best choice. This is performed by entering key words in a search screen. The application responds with the part number and name of all widgets and gizmos that meet the search criteria.

After determining which widget or gizmo is required, the user will need to locate one to fulfill the work order. The application must have a search
mechanism to locate all instances of specified parts. The user can then search through this list to determine the closest location of the part. If the part is located at a different site, a work order can be opened requesting shipment to the user.

Database administrators at the regional sites must also perform periodic inventory checks. This requires a listing of all equipment located at the site so that it can be compared with the equipment that is physically at that location. The inventory checks are performed to find and correct any errors that may be present in the database.

2.1.2 Performance Parameters

This system is being implemented to improve the efficiency of the corporation. In order to improve efficiency, the system must be faster to use or require less labor resources then the original manual mechanism that was in place. With the manual mechanism, regional users could complete work on approximately 20 work orders each day. To do this they spent a lot of time on the phone calling other sites to perform inventory checks and to assign new work orders. The new system must allow at least the same
production from the workers. Ideally, an automated system should allow more work to be performed each day.

Because this is an interactive system that is meant to improve corporate efficiency, certain performance parameters are imposed. Studies suggest that productivity of data entry tasks is influenced by the response time of the corresponding system. The recommended maximum response time for routine input and output operations, such as typing and cursor motion commands, is 100 msec. If the application requires additional time to provide a response, an indicator that the application is still working should be visible to the user (Cushman and Rosenberg, 247-248).

To improve user acceptance and productivity, the application should conform to data entry standards (Cushman and Rosenberg, 229-231). The user should be able to look at the screen and determine which fields are mandatory entry fields. Users should use a mouse to determine which field to edit or use the Tab key to move to the next field.

The system must also provide dependable connectivity for the regional users. The remote application must provide error detection and correction whenever
possible to ensure that the correct data is displayed to the user. Using the
TCP/IP protocol will ensure that data is accurately transmitted over the lines.
If an error occurs during the transmission, the receiving application will
request retransmission of the packet that was in error. Using TCP/IP will
ensure adequate dependability for the communications of the system.

In addition to the dependable communications, the system must ensure the
integrity of the data stored in the database. To do this, the system must
guarantee that the remote users are entering accurate information into the
 corporate database. All data that is input must be validated against the
standard business rules. These rules consist of checks on the range of
specified values and the data types of input fields. Additionally, some fields
may have values that are limited to a set of data that is stored in the database.

The remote application must be able to work with any sized database. The
size of the database will grow throughout the operational life of the corporate
database system. As the size grows, the only impact on the remote
application should be the added delay of transmitting a larger data set over
the low bandwidth communications lines. To prevent the overloading of the
communications lines when queries are performed, the remote application
must be designed to limit the number of records that are transmitted over the lines in one group. Assuming that the available bandwidth will average 4.8 kbps, the largest record transmittal should never exceed 10 Kbytes. With an available bandwidth of 4.8 kbps, 10 Kbytes will take approximately 15 seconds to transmit. This is faster than calling employees at the corporate headquarters or other regional sites to find the same information. Therefore, remote users will periodically accept this delay for large transmissions.

2.1.3 Use Requirements

The remote system will be used for approximately 8 to 10 hours per day per user at each regional site. The application will be started when the user logs onto the network, and will remain active until the user leaves at the end of their shift. Currently, the largest regional site may have up to 20 remote users logged on simultaneously. Because of the geographic dispersion of the regional sites, up to four of the regional sites may be in prime operation at once. Prime operation occurs during normal working hours for that location. If multiple sites are using the database concurrently, the response time may decrease because of the extra load on the database server. It is important that
the system take this variance in response time into consideration to prevent
time-out errors from occurring.

2.1.4 Security Considerations

Because of the remote locations in foreign countries, the XYZ Corporation is
very concerned with foreign industrial espionage. Industrial espionage can
occur if the foreign governments tap into the communications lines, or if
internal XYZ workers sell information to foreign buyers. To alleviate these
concerns, communications between the application and the database should
be encrypted. To further limit possible espionage damage, the application
should prevent the viewing of data by unauthorized users.

2.2 Requirements

Based on the Operations Concept, it is possible to determine the requirements
for the field application. The Operations Concept focuses on three areas:
Functionality, Usability and Security Requirements. The following sections
state the requirements for these three areas for the field application.
2.2.1 Functional Requirements

The following requirements represent the activities that the system must accomplish in the field. Based on the Mission Definition from the Operations Concept, a user at a regional site must be able to:

1. Determine which work orders are currently assigned to him/her
2. Determine which work order has highest priority
3. Create a new work order
4. Edit a work order
5. Re-assign a work order
6. Close a work order
7. Create a child work order assigned to a worker at any location
8. Determine the status of child work orders
9. Add a widget or gizmo to the database
10. Request a widget or gizmo from a different site, including the headquarters
11. Determine what piece of equipment is required for a specific function
12. Determine where a piece of equipment is located
13. Determine closest location for a widget or gizmo

14. Obtain a report of inventory stored at the site

### 2.2.2 Usability Requirements

The following state the requirements for usability that must be attained for the application in the field. These requirements contribute to the efficiency of the users at work and also add to the desire for them to change their practices and accept the use of this system. Based on the Performance Parameters and Use Requirements from the Operations Concept, the remote application must:

1. Allow processing of at least 20 work orders each day

2. Have a response time of 100 msec

3. Provide an indicator that the application is waiting for processing or communications (i.e. display an hour glass when the system is busy)

4. Conform to data entry and user interface standards (Cushman and Rosenberg, 229-231):

   - Clearly identify mandatory fields
   - Use mouse movements to choose next field to edit
   - Move to next field by pressing Tab key
• Provide Accelerator keys for expert users

• Provide an UNDO feature to reverse any unwanted action

5. Use TCP/IP to provide dependable communications transmissions

6. Apply appropriate business rules to provide data validation for user entries:

• Perform range validation

• Validate data type of input field

• Restrict data entry to a set of stored data

7. Account for delayed responses from the database server by waiting and not timing-out

8. Limit transmissions to a maximum of 10 Kbytes for large database returns

2.2.3 Security Requirements

The following security requirements are meant to prevent easy compromise of the data in the XYZ corporate database. Based on the Security Considerations described in the Operations Concept, the field application must:
1. Encrypt data sent to the corporate headquarters

2. Decrypt data received from the corporate headquarters

3. Prompt a user for a username and password to prevent unauthorized access to the database

4. Prevent a user from seeing data associated with other workers’ work orders

5. Allow only the database administrator to print a full inventory report
3 Functional Flow Diagrams

The requirements of the system operation have been used to develop descriptions of how the remote application will be utilized by the end user. This information is presented in graphical format in the following functional flow diagrams, Figures 3.1 to 3.6. Two levels of detail are shown for the operational flows.

Figure 3.1 shows the top level functional flow. After starting the application each user will view their assigned work orders. After the work orders are displayed, the user has the option of creating a new work order, editing an existing work order, adding a newly developed widget or gizmo to the database, or performing queries on the database. After each operation is performed, the user is returned to the view of their assigned work orders. At the end of the day, the user will stop using the application.

Figure 3.2 shows the breakdown of function 1.0, Start Application. User authentication is required before a user can access the database. After starting the application, the system will request a username and password. If the username and password are not correct, the user is given the chance to
revalidate the login. After a successful login, the user is allowed to view their assigned work orders, function 2.0. There are no lower level functions that a user performs to view the assigned work orders.

Once the user is logged on and viewing the work orders, four options are available. The first option is to create a new work order. Figure 3.3 shows the functional breakdown of creating a new work order. All work orders consist of general data, such as the date the work must be completed. After the general data is entered, the user can enter data that is specific to shipping requests or new product development. If a different group must perform an activity for the work order, a child work order is created. The same type of information is entered for all child work orders that are created. After all the information and children are created, the work order can be saved to the database.

Figure 3.4 depicts the breakdown of editing a work order. To edit an existing work order, the user must first select the work order to edit. After the work order is selected, any information about the work order can be updated, such as the status of the work order or any children work orders that are attached. Additionally, when updating the work order, it is possible to create new
children work orders to task different groups to complete parts of the parent work order.

Every new widget or gizmo that is developed must be added to the database. This is needed so that a user performing queries can always know where every piece of equipment is located. Figure 3.5 shows the breakdown of adding a new piece of equipment to the database, function 5.0. The first sub-function that is required is to enter the details about the equipment. These details are used in the queries to determine which piece of equipment will fulfill a specific need. After the details are entered, the location of the widget or gizmo must be entered so that other users can request shipments. The new piece of equipment is saved to the database after all the information is entered.

The final high level option that is available is to query the database. Figure 3.6 breaks this function into its lower level components. There are three types of queries that can be performed. Queries on the status of the work orders allow a user to show all work orders with a specified status. If no status criteria is given, all work orders will be returned sorted by the status. The work order assignee query returns a listing showing the people who are
assigned to each work order. Finally, an ad-hoc query capability will allow the user to specify the query parameters and sorting keys for the query.

Equipment queries work the same as the work order queries, with equipment location, equipment function and ad-hoc equipment queries being supplied. Finally, the database administrator will be able to print a full inventory report that can be used for the yearly inventory checks. The inventory report will list all equipment that is available at the database administrator’s location.
Figure 3.1 - Functional Flow Diagram Level 1
Figure 3.2 - Functional Flow Diagram Level 2A
Figure 3.3 - Functional Flow Diagram Level 2B
Figure 3.5 - Functional Flow Diagram Level 2D
4 Implementation Options

There are many options available that will allow regional users to access the corporate database. The easiest option is to keep the manual processes that are currently being used. However, this option does not satisfy the need to improve the corporate efficiency by removing manual processes. The options that remain for providing access to the corporate database typically fall into one of three categories:

- Use established methods and technology
- Use new methods and technology
- Combine the established and new methods

Many options are available within each category that can provide the ability for the regional users to input data and perform queries of the data stored in the corporate database. Because of the tremendous publicity of the World Wide Web, XYZ corporate leaders are trying to find ways of leveraging this technology in new products. Therefore, if new technologies are explored, the XYZ corporate leaders would like to focus on the possibility of leveraging the technology from the World Wide Web.
The following three options provide the ability for regional users to input data and perform queries of the data stored in the corporate database. Each option falls into one of the three possible categories and focuses the use of new technology of the World Wide Web.

- **Develop an application using a Database Interface Builder**

  The easiest way of providing this capability is to use the existing Microsoft Access application. This will provide the regional users with the exact same functionality that the users in the corporate headquarters have. The performance over the slow communications lines can be improved by optimizing the queries. Additional modifications can be made to the application to prevent large data transfers from occurring.

  Figure 4.1 shows the architecture for using a database interface application. All communications between the database interface application in the field and the database server take place via Open Database Connectivity(ODBC) over TCP/IP. A user in the field can use the developed application to add, update, and view data in the database.
- Use World Wide Web technologies to develop an HTML application

The XYZ Corporation can leverage existing World Wide Web technologies to provide the regional users with access to the corporate database. Using HTML version 2.0 forms, an application can be written to allow users to input data into the corporate database. Additional forms can be designed to allow users to submit query criteria. The results of the queries can be formatted into HTML pages for viewing at the remote sites.

Figure 4.2 shows the architecture for an HTML application. A WWW Browser is used at the remote sites to display the HTML forms of the application. A user in the field can input data into the appropriate fields in the form. Upon submittal of the form, the data is transferred via the HyperText Transport Protocol (HTTP) over TCP/IP to the Web.
Server located at the corporate headquarters. The Web Server then communicates with the database server via ODBC to update the corporate database.

For queries, the user enters query criteria into an HTML form. The query criteria is transmitted via HTTP to the Web Server at the corporate headquarters. The Web Server then sends the query request to the database via ODBC. The database server returns the results of the query to the web server where the results are formatted into an HTML page. This page is then transmitted to the browser in the field where the user can view the results of the query (Dieckmann, 51).
- **Develop an HTML application for queries and continue sending faxes**

Another option is to develop an application that only provides the regional users with the capability of querying the database. The regional users will continue to send faxes of their work to the corporate headquarters. Employees at the corporate headquarters would receive the faxes and perform the data entry tasks associated with entering the information into the corporate database. In order to improve the process of entering data at the corporate headquarters, templates for
the faxes must be created. These templates would be used within a standard word processor to provide fields for the user to input the data. When the faxes are received at the corporate headquarters, the formatted fax can be easily interpreted by the data entry personnel.

To improve the process, an Optical Character Recognition (OCR) application can be used to obtain information from the faxes received from the regional users. If the faxes are formatted properly, it is possible to develop an application for recognizing characters on typed faxes and parsing the information based on location on the form. This alleviates the need for data entry personnel at the corporate headquarters.

Figure 4.3 shows the architecture for using an HTML application to view data in the database while continuing to use faxes for adding data to the database. The query capability for this option works the same as the query capability in the fully functional HTML application. For data updates, a user at a regional site fills out the fax which is transmitted via the V.17 fax protocol to the headquarters. Once received, an OCR
application can read the fax and perform the updates of the corporate database.

Figure 4.3 - HTML Application and Fax Architecture
5 Evaluation of Alternatives

To evaluate the alternative options presented in Section 4, it is necessary to first establish the evaluation criteria. When evaluating system level alternatives, the evaluation criteria should be determined from the problem statement (Blanchard and Fabrycky, 67).

When reviewing the statement of need, four areas are prominent: Functionality, Performance, Dependability, and Development Resources. All three implementation alternatives will provide the required add, update and query functionality. In addition, all three alternatives also provide centralized data storage without the need to store any data at the regional sites. Therefore, based on the statement of need, the following criteria have been identified for evaluation.

1. Performance consisting of:
   - Query return performance
   - Data update performance
   - Form data entry performance
Performance will be evaluated on a scale from 0 to 5. A value of 0 means that the application will not function without timing out. Only values of 4 and 5 will meet the performance requirements stated in section 2.

2. Dependability consisting of:
   - Communications dependability
   - Data integrity

Dependability will be evaluated on a scale from 0 to 5. A value of 0 means that the application cannot provide the dependability required to use the application at a regional site. Values of 4 and 5 will meet the dependability requirements for the client application.

3. Development resources to implement:
   - Labor required to complete
   - Completion date for read only capability
   - Equipment required to complete

Development resources will be evaluated on the basis of the present value cost of developing the client application and the date the application can be completed.
Evaluating the above criteria will decide which implementation approach will provide the best means of allowing regional users access to the corporate database. No basis was determined for providing weights to the evaluation criteria. Because the XYZ corporation considers each criteria to carry equal weight and no previous experience with these criteria was determined from research, no weighting is applied to the evaluation criteria.

The development resources required to implement are all present value costs. These costs consist only of the labor costs involved in development and any additional hardware or software that is required to develop the client application for the regional users. Typically, system cost is determined based on the life cycle cost for the system which includes the costs for research and development, production and construction, operation and support, and retirement and disposal (Blanchard and Fabrycky, 501). However, for the client application there are no costs for production, construction, retirement or disposal. The only costs of concern for the XYZ Corporation are the costs to perform research and development of the software for the client application and the costs for Operations and Maintenance (O&M).
For the problem of providing access to the corporate database for regional users, the difference in O&M for the three systems is negligible. All three systems will have discrepancy reports that must be fixed and requests for changes that must be added. The cost of implementing these changes will be the same for the three alternatives because the time necessary for maintaining the systems should be equivalent for all three alternatives. Since the maintenance time is the same, the maintenance costs for the different systems will be equivalent because the XYZ Corporation does not consider the specific skills of an employee when determining labor costs. The only factor in the labor cost is the level of the employee (i.e., junior programmer vs. master programmer). Because the maintenance costs will be equivalent, the only cost that was considered in the system cost was the research and development costs that are required for development of the client application for the regional users.
5.1 Database Interface Application

5.1.1 Performance Evaluation

A database interface application communicates with the SQL Server through ODBC running on top of TCP/IP. The use of TCP/IP as the transmission protocol provides performance improvements over the use of non-routed transmission protocols. However, ODBC adds a substantial amount of overhead to the communications lines. Every time the application communicates with the database server, the server will request user validation. This request must travel across the slow communications lines. After being received by the client, the request must be answered. The server then sends an acknowledgment telling the client that the server will accept and process the information that will be sent.

For query returns and data updates, the additional overhead will have an impact on performance. For both of these operations, the overhead associated with establishing the trusted communications with the database server only occurs once per query return or data update. When tests were performed on sample queries over low speed communications lines, ODBC
time-out errors were periodically received. Therefore, queries performed with the application will not meet the performance requirements stated in Section 2. Data updates were not as susceptible to the time out errors because of the smaller set of data being transmitted over the communications lines.

When field level validation is used, a significant performance impact will be noticed for data entry. This is because many of the fields on the form have validation against data in the database. This is done to improve the data integrity, but it will cause a significant performance impact at the regional sites over the slow communications lines. To alleviate this performance impact, the application can be designed to use form level validation instead of field validation. This will enable field users to have adequate form data entry performance.
Performance Summary:

- Query return performance: 2.5
- Data update performance: 4
- Form data entry performance: 5
- **Overall Performance: 3.83**

5.1.2 Dependability Evaluation

Communications between the database interface application and the database server occur over TCP/IP. The Transmission Control Protocol (TCP) was designed to provide dependable communication over reliable and unreliable networks (Stallings, 579). Every TCP data packet contains error checksums. If the checksums on the received packet are not valid, then the receiver asks the sender to retransmit the packet. The sender will also retransmit the packet if the sender does not receive an acknowledgment from the receiver in a specified time period (Stallings, 585). These error mechanisms ensure dependable communications between the client and server.

The second part of the dependability of the corporate database is ensuring the correctness of the data that is stored. This is the data integrity. To ensure the
integrity of the data, it is important to check that the information being supplied meets specified business rules, such as falling within proper date boundaries or being constrained to one of a list of items. Data integrity can be ensured by using field level or form level data validation. With field level validation, checks are made to ensure that the entry meets specified criteria after the information is entered in a data entry field. With form level validation, all of the data on the screen is verified before the information is stored in the database.

**Dependability Summary:**

- Communications Dependability: 5
- Data Integrity: 5
- **Overall Dependability:** 5

### 5.1.3 Development Resource Evaluation

The easiest way to implement a database interface application is to use the existing Microsoft Access application that is being used in the corporate headquarters. However, the Microsoft Access Application will require considerable optimization in order to perform over the 9.6 kbps
communications lines. This optimization will require studying the
performance of the existing application, determining what areas can be
optimized, and performing the actual optimization of the code. Part of the
optimization entails rewriting the queries to return only information that is
required. Also, parts of the application can be rewritten to start displaying
the returned results before the entire data set is returned. The entire
optimization effort will require 1 systems engineer and 2 developers working
6 months to complete. The average cost per labor year is $100,000 for the
XYZ Corporation. This cost includes salary, benefits, vacation, and sick
time.

When reusing the existing Microsoft Access application, it is not possible to
provide a read only capability to the corporate database. This is because the
entire application must be delivered to the users, including the data updates.
In order to provide an application that will work in the field, the entire
application must be optimized, including the data updates.

No additional equipment is needed to implement the Microsoft Access
application. The current development environment can be reused for the
optimization effort. Additionally, all licenses have been purchased for using Microsoft Access throughout the corporation.

**Resource Cost Summary:**

- Labor Cost: $150,000
- Equipment Cost: $0
- **Overall Resource Cost: $150,000**

### 5.2 HTML Application

#### 5.2.1 Performance Evaluation

With the HTML application, communication with the corporate database must occur through a separate web server. The HTML application communicates with the web server via HyperText Transport Protocol (HTTP) running over TCP/IP. HTTP is a protocol that was developed specifically for low-speed communications (Berners-Lee, Fielding, and Frystyk). By running over TCP/IP, performance of HTTP is improved through the use of a routed protocol. The web server will be connected to the database server on a high-speed token ring local area network running at 16 Mbps. Even though the
web server will be communicating with the database server through ODBC, the overhead associated with this communication will not be noticed because of the speed of the network communications.

The HTML application should have excellent performance for queries and data updates. These database operations require data to pass from the application to the database. This is a process with little communications overhead for this implementation. When filling out the forms for data entry, there is no interaction with the database. Therefore the only hindrance to the speed of filling out the form is the user’s ability to type.

**Performance Summary:**

- Query return performance: 5
- Data update performance: 5
- Form data entry performance: 5
- **Overall Performance: 5**

### 5.2.2 Dependability Evaluation

The HTML application will use TCP/IP as the transmission protocol for communications between the client application and the web server. TCP/IP is
also being used as the protocol between the web server and the database server. This use of TCP/IP will ensure high communications dependability.

The HTML application must also ensure the integrity of the data that is stored in the corporate database. Unlike the Microsoft Access application, the HTML application cannot perform processing of the data on the client side. This makes it impossible to perform field level data validation. However, to ensure the integrity of the data being input into the corporate database, form level data validation can be used. For this implementation, the data will be verified after the form is submitted for entry into the database. If any entries are invalid, the application will ask the user to reenter the information for the invalid fields.

**Dependability Summary:**

- Communications Dependability: 5
- Data Integrity: 5
- Overall Dependability: 5
5.2.3 Development Resource Evaluation

The HTML application must be developed from the beginning. However, since the application will be modeling an existing application, the design of the HTML application is fairly well defined. The only changes to the design that will be required are due to implementation differences between HTML and Access Basic. All of the queries and data updates are defined in the Microsoft Access application. These can be directly ported to the HTML application. The only new design will be implementing the form level validation as compared to the field level validation currently used in the Access application.

The entire development effort for the HTML application will require 2 systems engineers and 4 developers working 6 months to complete. The development of the application with only query capabilities will take the same 2 systems engineers and 4 developers 2 months to complete. The average cost per labor year is $100,000 for the XYZ corporation. This cost includes salary, benefits, vacation, and sick time.
No additional hardware equipment is needed to implement the HTML application. The current development hardware can be reused for the development effort. However, it will be necessary to acquire a web server, a web browser, and development tools such as scripting languages and HTML editors. Many of the tools that can aid in development are available for free off of the Internet. The only purchases that are required are for the web server (approximately $2000) and the web browser (approximately $50 per license). A good estimate for the software required to develop the HTML application would be approximately $2500. This is based on using products from Netscape, the current industry leader in Internet technologies.

**Resource Cost Summary:**

- Labor Cost: $300,000
- Equipment Cost: $2500
- **Overall Resource Cost: $302,500**
5.3 HTML Application with Fax Data Entry

5.3.1 Performance Evaluation

The HTML application will only be performing queries. The query performance of this implementation should be the same as the full HTML only application. For data updates, the performance will suffer. To improve the perceived performance of data updates for the user at the regional site, the built in fax capability in word processors should be used. The user can fill out a template and then fax the document to the corporate headquarters. Once received, an employee at the headquarters will have to start the process of transferring the fax from the received fax queue to the OCR application where the work order information can be read. To ensure data integrity, an employee at the headquarters should verify and correct the data before accepting it for entry into the database. From the regional user’s perspective, the data entry performance will not take any additional time compared to completing the original fax.
Performance Summary:

- Query return performance: 5
- Data update performance: 4
- Form data entry performance: 5
- Overall Performance: 4.67

5.3.2 Dependability Evaluation

The HTML application requires the use of TCP/IP as the transmission protocol for communicating between the client application and the web server. TCP/IP is also being used as the protocol between the web server and the database server. This use of TCP/IP will ensure high communications dependability for the HTML portion of the application.

In order to ensure the data integrity of information obtained from the field, it is necessary to have an employee at the corporate headquarters review the data before it is entered into the database. This will ensure that the data is valid and that no errors were introduced in the faxing and OCR process. If any entries are invalid, a user at the corporate headquarters must correct the error or contact the user at the regional site to find out what the correct
information is. Although this method ensures the integrity of the data, it cannot be performed in an entirely automated fashion. Using manual data verification will lower the overall integrity of the data stored in the database, because a human operator is likely to make mistakes over time. However, the integrity of the data should be equivalent to the current levels that are achieved with an entirely manual process for entering data into the database.

**Dependability Summary:**

- Communications **dependability**: 5
- Data Integrity: 4
- **Overall Dependability**: 4.5

### 5.3.3 Development Resource Evaluation

The HTML application for this implementation only consists of queries. These queries are all well defined in the original Microsoft Access application and can be directly ported to the HTML application. For the query only HTML application, the entire development effort will require 1 systems engineers and 2 developers working 4 months to complete.
The other part of this implementation is entering information from the faxes received from the field into the corporate database. Many commercial applications exist for OCR. These high quality products can be leveraged to provide an electronic copy of the received fax. The only development would be to design the template for remote data entry, and the program to parse the electronic copy and enter the information into the database. Part of the parsing program must be a view and edit capability so that users at the corporate headquarters can verify and correct the data. The development effort for the data entry portion of the project will require 2 systems engineers and 2 developers working for 6 months.

No additional hardware equipment is needed to implement the HTML portion of the application. The current development hardware can be reused for the development effort. However, it will be necessary to acquire a web server, a web browser, and development tools such as scripting languages and HTML editors. Many of the tools that can aid in development are available for free off the Internet. The only purchases that are required are for the web server(approximately $2000), the web browser(approximately $50 per license), and scripting languages. A good estimate for the software required
to develop the HTML portion of the application would be approximately $2500. This is based on using product from Netscape, the current industry leader in Internet technologies.

For the fax portion of the implementation, a high quality fax-modem and OCR application are required. This should cost approximately $1000.

Resource Cost Summary:

- Labor Cost: $300,000
- Equipment Cost: $3500
- Overall Resource Cost: $303,500

5.4 Determination of Implementation Strategy

Table 1 shows a summary of the evaluations for the three implementation options. Values of 4 and 5 represent acceptable levels for performance and dependability. These values correspond to evaluations that will meet the requirements set forth in Section 2.

Based on the evaluations, the database interface application will not provide an acceptable level of performance. All of the options provide acceptable
dependability. Even though the cost of implementing the database interface application is at least half the cost of the other implementations, the performance and completion date will not satisfy the requirements. Both of the HTML applications meet all of the stated evaluation criteria. However, based on the completion date and resource cost, the HTML application without faxes should be implemented.

<table>
<thead>
<tr>
<th>Table 1 - Summary of Evaluation Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
</tr>
<tr>
<td>Database Interface Application</td>
</tr>
<tr>
<td>HTML Application</td>
</tr>
<tr>
<td>HTML Application with Faxes</td>
</tr>
</tbody>
</table>

To minimize the cost impact, the HTML application should implement the query capability first. This will provide the regional users with a viewing capability for the corporate database, meeting the requirements for full functionality of the database system. After the query capability is provided,
the corporation will provide the necessary funding to implement the data entry portion of the HTML application. The query capability can be implemented with 2 systems engineers and 4 developers in 2 months. Including equipment costs, providing query only capability to the field by October 1 will only cost the corporation $102,500.
6 Requirements Validation

Before making the final decision to choose the HTML application as the implementation method, it is necessary to ensure that the requirements set forth in section 2 are met. The system requirements were broken into three high level groups: functional, usability, and security.

6.1 Functional Requirements Validation

All of the functional requirements can be met by the HTML application. Many applications have been developed to provide add, update, and query capability to relational databases through World Wide Web interfaces. One example is the Human Genome Project which uses one of the largest relational databases with a World Wide Web interface. The Human Genome Project consists of a decentralized team of researchers that are attempting to determine the human genetic code. Researchers submit newly discovered data to the database through a World Wide Web interface on the Internet. Interfaces to the database also exist to allow researchers to search the database for findings by other researchers(Duncan, 405).
Based on the success of the Human Genome Project, it is possible to see that a World Wide Web interface can provide the add, update, and query capabilities necessary to give the regional users access to the corporate database. Many of the functional requirements are satisfied by migrating queries from the original Microsoft Access application into an HTML format. The remaining functional requirements are implemented by developing add and update screens for the information. The hardest part of implementing the add and update functionality is performing data validation. However, it is possible to validate the data entry and inform the user of any errors before storing any data in the database.

6.2 Usability Requirements Validation

The most important usability requirement is that a regional user will continue to process at least 20 work orders each day. After the first phase of the implementation, the regional users will still be sending faxes detailing their activities to the corporate headquarters. However, the regional users will be able to work more efficiently because they will not be reliant on users at headquarters to provide needed information. This should enable workers to
process at least the same amount of work orders each day. When the data entry portion of the application is completed, the users will no longer be required to write faxes to headquarters. This will save time because the users will only have to complete fields in the entry form, not write textual descriptions of their activities. Additionally, once the form is submitted, the regional users are able to process the next work order. With the original fax transmission, it is necessary for the regional users to watch the faxes and ensure that the transmission takes place correctly.

When measuring the response time as the time for the application to accept entry in one field and move to the next field, it should not be difficult to ensure a response time of 100 msec with the HTML application. This is because no processing occurs in the client application. Therefore, the only delay will be the inherent delay in the computer to accept the entry and move to the next field. A delay is likely to arise when the user submits the query to the database. However, World Wide Web browsers provide two indicators that the application is waiting. First, the mouse pointer will turn into an hourglass. Second, the status bar will indicate that the system is waiting for the remote server to respond.
All of the data entry and user interface standards can be met by the HTML application. The browser must provide the support for these interface standards, not the actual pages that will be developed to interface with the database. Incorporation of the standards is ensured by using the Netscape browser which provides all of the necessary features.

The remaining usability requirements must be implemented by the server applications running at the corporate headquarters. First, TCP/IP will provide the communications protocol between the headquarters and the regional sites. The draft Hypertext Transfer Protocol Specification by Berners-Lee, Fielding, and Frystyk states that HTTP communications, the protocol used for HTML applications, generally takes place over TCP/IP. Second, the web server and browser can be configured to prevent time-outs when there is a delayed response from the database server. Finally, the scripts running at corporate headquarters can be developed to limit the transmission of large database returns so that a maximum of only 10 Kbytes is returned. This will be implemented by breaking the large return into smaller data sets, each less than 10 Kbytes, that are returned separately.
6.3 Security Requirements Validation

Many of the security requirements are implemented through the web server and browser. Data encryption is ensured by using the Secure Sockets Layer (SSL) that is becoming the standard for secure communications for World Wide Web applications. SSL provides up to 128 bit encryption between the server and client. 128 bit encryption is nearly impossible to crack using a brute force method (Stein, Q56).

The web server and browser also provide the request for username and password when accessing the database. With the original access application, the user is authenticated by the database server. However, with the HTML implementation, user authentication will occur by the server running the web processes. This will prevent any user who does not have a valid account on the web server from accessing the database.

The last two security requirements must be implemented by the actual scripts that will obtain data from the corporate database. First, in order to prevent users from seeing data associated with other workers' work orders, the scripts must perform an additional check when the query is implemented.
The server will know the username of the regional user accessing the database. Since the username is known, the scripts can be written to restrict access to work orders that are being worked by that username. Second, since the database tracks the role of each user, the application will know whether the current user is a database administrator. The scripts for printing the full inventory report must prevent users who are not database administrators from performing this operation.
7 Risk Identification

There are risks involved in any implementation plan. The best way to handle those risks is to identify them early and develop mitigation plans for handling those risks. Without proper risk mitigation, a project can easily fail. The following risks have been identified for the HTML application:

- Continuous evolution of new WWW technologies
- Lack of WWW development experience in the XYZ Corporation
- Security of WWW applications

7.1 New WWW Technologies

One of the greatest risks with the HTML application is the continuous improvement and expansion of the WWW technology. This is exemplified by the continuous expansion of HTML beyond the standards of HTML version 2.0. Both Netscape and Microsoft are offering competing extensions to HTML. These extensions can do a lot to enhance a web page, but can also create serious limitations for viewers without the proper browser. When creating the pages for the HTML application, the standards set forth in
HTML version 2.0 should be followed. Providing access to the corporate
database does not require any of the extensions that are offered by competing
browser developers. This is not a serious limitation because it is nearly
impossible to provide acceptable performance over the slow communications
lines if anything besides pure text is transmitted on the pages.

Another risk that arises because of new developments in WWW technology is
the desire to wait for the latest and greatest product that is coming out shortly.
When reading the technology papers it is always possible to read about a new
product that will revolutionize the World Wide Web. Unfortunately, there is
not time in the development schedule to wait for these products to
materialize. The best mitigation method is to only use tools that are available
now. When performing product evaluations, future products should not be
evaluated because of the risk that they may not be available when promised
by the developer.

7.2 Development Experience

The XYZ corporation does not have any experience in developing products
using WWW technology. This application will be the first HTML product
developed within the Information Systems Division. This is a significant risk because it is very difficult to develop an application without any experience in the chosen development environment. For the XYZ corporation, this risk is not as significant because the developers all have a deep understanding of the corporate database and the queries and updates that are used in the Microsoft Access application. This knowledge must now be migrated to an HTML implementation. If any developers have experience in HTML development, they should be part of the development team.

There are two options if no one within the organization has development experience with HTML. The first option is to hire external developers with HTML experience. This poses problems due to time constraints on the hiring process. Additionally, these developers will lack the critical knowledge associated with the existing application. The second option is to train the developers in HTML development. With proper hands on training, the developers should be able to rapidly learn HTML development techniques. They will then be able to apply these techniques to the development of the HTML application.
7.3 Security

Security is the greatest concern of individuals using the World Wide Web. There have been significant discussions about the security of transactions that take place on the World Wide Web. However, there are mechanisms that will enable a secure database interface.

The first level of security is provided by using independent leased lines. This prevents individuals without access to the XYZ corporate buildings from gaining access to the system or the information that is traveling on the communications lines. However, it is still important to implement a system to prevent unauthorized employees from accessing the corporate database. Password protection can be enabled on the web server at the corporate headquarters. This will require any user from the regional sites to provide a username and password the first time they access the web server, no matter what page on the server the user accesses to start the session. The user is denied access to the server until a valid username and password are provided.
8 Conclusion

This project described a process that can be used to evaluate alternatives.

To demonstrate this process, a case study was presented in which the XYZ Corporation followed the described process to evaluate alternatives and determine the best means of providing regional users access to the corporate database over low speed communications. In the case study, the following steps were performed:

1. Definition of the need
2. Determination of the system requirements
3. Functional analysis
4. Determination of the implementation options
5. Evaluation of the implementation options
6. Requirements validation
7. Risk identification

Three alternatives were identified that would satisfy the need for remote access to the corporate database. The first alternative was to optimize an existing database interface application that is used by employees at the
corporate headquarters. The other two options used WWW technology to provide access to the corporate database. One option was to create an HTML application that provided add, update, and query capabilities. The second option was to create a query only HTML application and continue the practice of having regional users provide data additions and updates via faxes transmitted to employees at headquarters.

After the evaluation of alternatives, the best means for providing access to the corporate database is to develop a new HTML application. The HTML application should be designed to provide the ability to add, update, and query the corporate database. In addition to evaluating the HTML application against the specified alternatives, it is necessary to ensure that all requirements can be met by the chosen implementation. With the HTML application, it is possible to provide all stated requirements.

As with all projects, there are risks involved with implementing a specified option. The final part of the decision process was to determine the risks involved with implementing the HTML application. The constant evolvement of WWW Technologies, the lack of WWW development experience, and WWW security issues were identified as the three main risks involved with
implementing the HTML application. However, during the risk identification, mitigation factors were identified to minimize these risks during implementation of the application.

The recommendation of this project is to design and implement the full HTML application. However, to work within the corporate budget constraints, the application should implement query only capabilities before the end of the fiscal year, October 1, 1996. After this ability is provided, the corporation will provide the necessary funds in next year’s budget to implement the add and update capabilities.
Appendix A - Acronym Listing

kbps  Kilobits per Second
HTML  HyperText Markup Language
HTTP  HyperText Transport Protocol
Mbps  Megabites per Second
OCR   Optical Character Recognition
ODBC  Open Database Connectivity
TCP/IP Transmission Control Protocol/Internet Protocol
WWW   World Wide Web
Bibliography


