Project Number: AHH 0801

Manual Wheelchair Handbook Study for the Massachusetts Department of Mental Retardation

An Interactive Qualifying Project

Submitted to the Faculty

of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

_____

Daniel J. Asselin

_____

Nikolas K. Ledoux

_____

David C. Willens

Date: May 13, 2008

Approved:

Keywords:

1. Wheelchair Maintenance
2. Assistive Technology
3. Employee Training

_____

Professor Allen H. Hoffman

_____

Professor Holly K. Ault

Abstract

This Interactive Qualifying Project was sponsored by the Massachusetts Department of Mental Retardation in an effort to improve their ability to repair manual wheelchairs efficiently. Previous IQPs at Worcester Polytechnic Institute had created a preliminary version of a maintenance manual for use by the direct care staff at DMR group homes. For this project, we created a fully-online resource with a revised handbook. The new handbook was simplified and focused on improving communication among direct care staff, supervisors, and vendors. Following the creation of these new resources, they were the subject of a test program to be conducted at four DMR group homes. The result of the test program demonstrated some improvement in the direct care staff's knowledge, but a solely online resource was shown to be impractical for the given logistics of DMR homes.

Acknowledgements

We would like to express our sincere gratitude to both of our DMR liaisons, Thomas Mercier and Bruce Klockars. They donated their invaluable knowledge and time throughout the course of the project and were ever willing to help when needed. In addition, the directors of each of the facilities we visited, Sue Anderson of Providence Street, Worcester, MA, Kerry McGowan of Delawanda Drive, Worcester, MA, Karine Joseph of Leicester, MA, and Harry Violette of Uxbridge, MA, showed impressive patience and a willingness to support us in any way they could. Our two advisors, Profs. Allen Hoffman and Holly Ault were indispensible and kept us headed in the right direction. Prof. Joseph Petruccelli provided valuable statistical analysis advice. Finally, thanks also go to all direct care staff members who participated in the project.

Contents

Introduction and Problem Statement

The Massachusetts Department of Mental Retardation requested that Worcester Polytechnic Institute look into improvements for their current manual wheelchair repair, inspection, and maintenance procedures. This IQP was advised by Profs. Allen H. Hoffman and Holly K. Ault and was led by students Daniel J. Asselin, Nikolas K. Ledoux, and David C. Willens. Our liaison with DMR was Thomas Mercier, the Director of the Kelly Assistive Technology Center in the Northeast Region located in Hathorne, Massachusetts.

The main goal of this project was to supply the direct care staff with reference documentation to help them identify important wheelchair components, which would enable them to communicate effectively with repair personnel and allow them to perform limited repairs. Other objectives were to develop a formalized system of reporting problems with wheelchairs and to evaluate the success of our proposed improvements. A goal of this project was to improve the availability and useful life of DMR's wheelchairs for the residents of the DMR-affiliated group homes. The project focus was specifically on manual wheelchairs; power wheelchairs do not come under its purview.

The project documentation was based on that produced by two previous IQP groups on the same topic. One IQP was devoted to the development of a website and set of videos (Young & Holmes, 2001). The other updated this information and created a new wheelchair maintenance manual and a new website (Trimby, Sarcione, & Kopec, 2004). DMR indicated to us that the content of the repair manual and checklist required further improvements and updates before it could be implemented. As part of this project, we revised the manual to ameliorate its clarity and usability for DMR's staff members. To that end, we elected to divide the documentation into

two parts: one for the general reference of all staff that includes procedures to follow in the event of problems and one for a designated wheelchair inspector that includes basic maintenance procedures.

We made the documentation available as a web-based resource, accessible to all staff. This is foreseen by DMR to be the first step in a gradual conversion to an increasingly web-based operation.

The revised procedures and documentation were implemented via a training program proposed by WPI. To measure its success, we executed pre-testing and post-testing of participating staff members, including direct care staff, their supervisors, and wheelchair vendors. The testing was carried out at four Worcester County group homes, two of which will have been the recipients of more extensive interaction with WPI, and two of which will have been asked to begin without any earlier guidance from WPI.

We demonstrated that our revisions and recommendations produced a more efficient protocol for managing wheelchair-related issues, from problem discovery to return of the repaired wheelchair. Based on these results, we offered suggestions for future study and improvement, whether part of a future IQP or otherwise.

Background

This project was designed as a follow-on to two previous IQPs completed by Christopher Kopec, Adam Trimby, and Joe Sarcione in 2004 and Andrew Young and Ethan Holmes in 2001. The goal of these earlier projects was to develop a maintenance manual and accompanying website for the Massachusetts Department of Mental Retardation's wheelchairs . The projects focused solely on manual wheelchairs, and the maintenance manual was primarily designed as a print-based resource.

Our project was initially designed to evaluate the effectiveness of these resources in improving the maintenance procedures in place at DMR. The goal was to determine how well the previous IQP's results worked in this setting. DMR had initially proposed relatively minor revisions to the documentation before a thorough test program would begin. Based on the data provided by DMR, we believed that these revisions would require only a short period of time to complete. However, it quickly became clear, based on our discussions with DMR's representatives, that the maintenance manual required more revisions for use by the intended audience, the direct care staff at DMR group homes.

The Department of Mental Retardation currently does not have standardized procedures that are followed in the event of a wheelchair problem. There is also no schedule for routine inspection or preventive maintenance conducted by on-site staff. Repairs are requested and conducted only when a major problem develops. This often results in extended wheelchair downtime, on the order of three to four weeks, and unnecessary repairs. Repairs are handled through the wheelchair dealers, who often make multiple visits to diagnose a problem, order parts, and effect a repair. Problems are reported through an ad hoc method, whereby there is no

dedicated person assigned to handle wheelchair maintenance issues for each home. Additional knowledge of the parts of a wheelchair on the part of the direct care staff in each home would be beneficial to an efficient repair protocol. When problems are discovered, there is no standardized record-keeping mechanism in place at the individual group homes that permits pertinent information to be gathered and recorded for future reference. The information flow for this present system is shown in Figure 1.

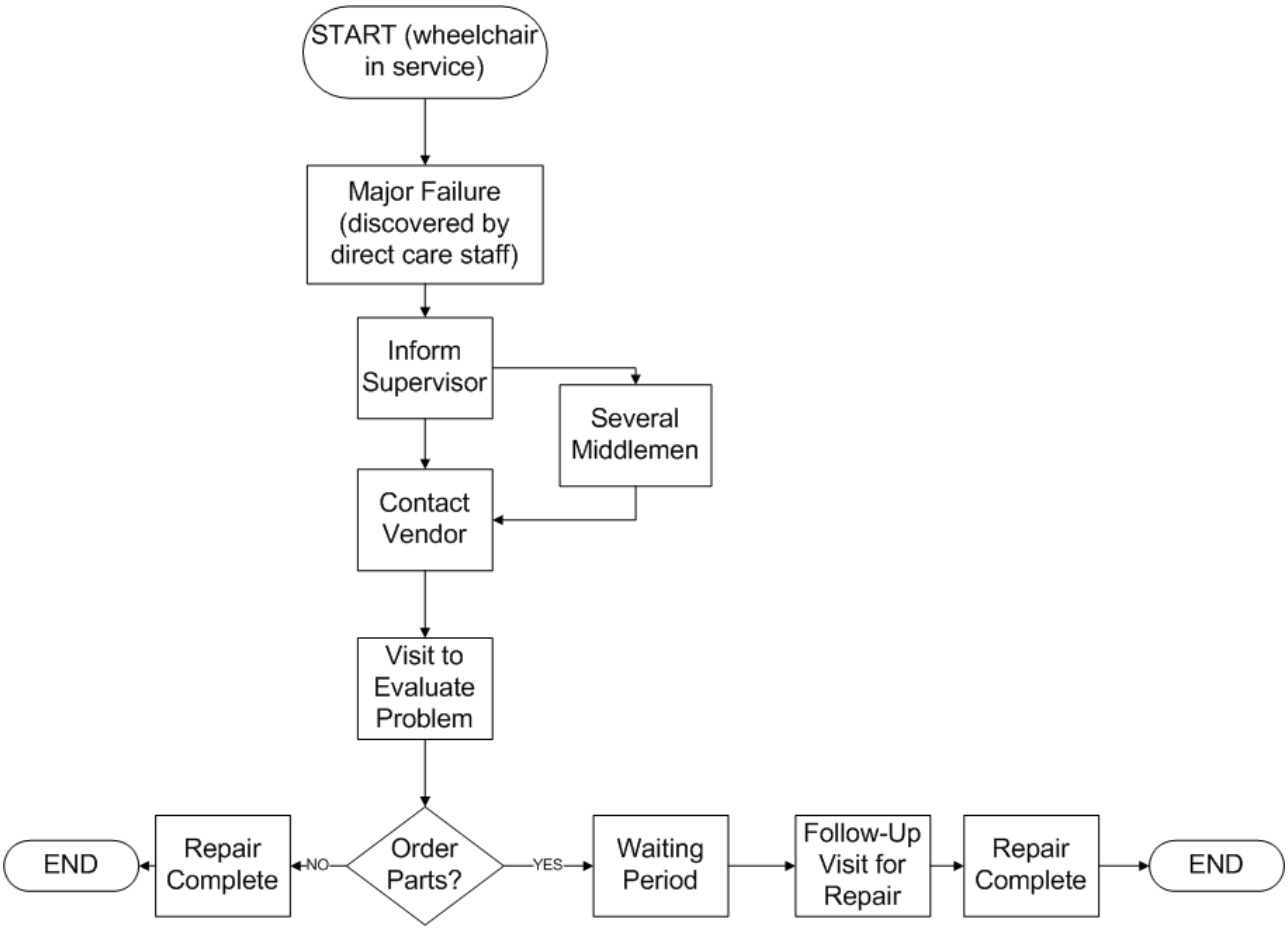


Figure 1: Current Process

We were initially given a list of specific revisions for the maintenance manual, checklist, and website. These revisions were primarily concerned with updating the content to reflect more modern wheelchairs, correcting minor errors, and removing some repairs considered too involved for direct care staff to complete. The website also required updating of its links section, as it had been nearly four years since its creation. DMR's position was that its staff should have better education in wheelchair terminology to facilitate effective communication with repair technicians. DMR desired to implement an inspection to be conducted during routine cleaning procedures. Cleaning is performed at night, when the wheelchairs are not in service. Such an inspection would be aided by a revised version of the original checklist adapted by the previous IQP group from one developed by Ohio State University (Trimby et al., 2004).

The manual required revision in several areas to improve its usability. The content was written using industry jargon and assumed a higher degree of mechanical ability than is expected of the direct care staff. This problem was exacerbated by potential English as a second language issues among the third-shift employees. DMR preferred that the direct care employees focus only on the most minor of repairs and learning the names of the important parts of wheelchairs. This would enable better communication between the staff and wheelchair repair specialists, with the goal of reducing the time necessary to complete repairs. Instead of a print-based manual, the Department wished to create an online resource which would serve as a prototype for future DMR web-based expansion.

DMR suggested that the new manual include an introductory list of warnings and cautions to prevent basic problems. They specifically wanted staff to be aware of fasteners, over-tightening, and the symmetric nature of wheelchairs. That is, staff could identify a replacement

part by using the opposite side of the wheelchair as a guide. Overall, the manual should be user-friendly and accessible to the lay person.

Communication was emphasized as being the major problem associated with the current system; the actual repairs take very little time. Most of the wasted time is spent waiting for vendors to visit the facility to identify problems. If staff could more accurately communicate the nature of a problem to the repair technicians, this initial visit could be eliminated. Furthermore, regular inspections would help discover problems before they become major issues that impact safety, cause extended chair downtime, and increase costs. This extended period of unavailability is especially difficult for wheelchair users because many have customized seating systems which cannot be easily replicated on temporary replacement chairs. Consequently, it is vital to return chairs as quickly as possible. One way to correct this problem is to improve the method by which repair issues are brought to the attention of repair persons. Problems currently can be relayed through multiple individuals before reaching the appropriate repair personnel. DMR would like to see this process streamlined through the addition of a standard maintenance issue reporting procedure, aided by web-based references.

With regard to the most recent website initially developed by the previous IQP (Trimby et al., 2004), the current configuration is inaccessible for people with low vision. All pages that appear on Massachusetts-sponsored websites must be in compliance with state standards that are modeled after those written by the World Wide Web Consortium. Due to the current website's use of JavaScript and the lack of appropriate contextual information for screen readers, people with visual impairments cannot use the site in its entirety. Before the results of this project can be implemented throughout the DMR system the website will have to comply with these standards. However, since this study is limited in its scope and there are no present employees with visual

impairments who will be involved, we elected to update the previous design for the initial testing period. Testing with the current design will also expose flaws in the site design that will need to be remedied prior to general adoption.

In consultation with DMR and our advisers, we elected to alter the focus of the project. Rather than investigate the effectiveness of the existing manual, we chose to spend significantly more time revising the current documentation to meet DMR's needs. The actual pilot program shifted to evaluating whether the new handbook would prove a useful tool for the staff members and succeed in communicating basic wheelchair information. As part of this reorientation, we directed research toward the development of an effective user manual to communicate clearly to the staff.

As background, the project group visited two DMR-affiliated group homes in Worcester. The first is located at 197-199 Providence Street and is operated by the state of Massachusetts. The director is Susan Anderson. The second is a privately-owned and operated facility located at 153 Delawanda Drive. This facility is run by the Seven Hills Foundation and directed by Kerry McGowan.

During these visits, we were able to inspect several of the manual wheelchairs in use by the residents and gain experience with wheelchair features and common problems. For example, backpacks hung on the headrests of chairs, loose wheel lock assemblies, wheel wear, missing anti-tip devices, and seatbelts were the source of many issues. Most of the issues that were described are not intended for repair by direct care staff but should be recognized and reported promptly to supervisors.

The staff expressed an interest in the project due to their own experiences with the lack of a unified communications system and the long wait times for wheelchair repairs. They also noted that Internet access could be made available as required but that many of the staff were unfamiliar with more advanced computer skills. It was noted that some newly hired employees lacked a good working knowledge of wheelchairs and what should be done in the event of a problem. There was frustration with the current repair process.

The system in place at Providence Street was representative of DMR's group homes. There was no standard method for identifying and reporting problems, no inspection schedule, and no regular maintenance. The facility at Delawanda Street, run by the Seven Hills Foundation, had the beginnings of an organized system in place. This was created at the behest of their wheelchair supplier, Ultimate Mobility located at 1158 Main Street, Worcester, MA, which supplied them with a checklist for cleaning, inspection, and maintenance, recommendations for a repair tool kit, and protocols for collecting and documenting information about their wheelchairs. This facility has complied with their recommendations and purchased an extensive tool kit, including English and metric Allen wrenches, ratchets and sockets, adjustable wrenches, screwdrivers, and a full set of box wrenches. Some of the staff were overwhelmed by the size of this tool kit and were not comfortable with the proper operation of hand tools. The staff undergoes regular in-service training conducted by Ultimate Mobility regarding cleaning, basic maintenance, and small repairs involving minor disassembly. Wheelchairs are cleaned and inspected twice daily, and all externally-performed repairs are accompanied by an extensive record-keeping and follow-up process. To that end, this facility has been able to minimize the number of diagnostic visits from the vendor by carefully explaining the problem, with the help of a wheelchair nomenclature diagram.

In consultation with Tom Mercier and Bruce Klockars we have determined which repairs should be conducted by direct care staff and which should simply be reported and referred for professional attention.

Literature Review

In the course of our research, we have found several areas to be relevant to our project. These include the planning of clinical trials, good user manual design, and the design of surveys and interviews.

Clinical Trials

A review of the published literature concerning clinical studies and wheelchair maintenance programs revealed much that proved to be useful in formulating our own study and developing a maintenance test program. We examined only those studies that used questionnaires or surveys as a means of gathering data, as this method was the primary way we collected information on the success of our program. It was important to examine other studies for the proper methodology and analysis of the collected data.

We found numerous studies that related to the evaluation of wheelchair maintenance and training systems. In the course of examining these studies, we found common features that helped us in developing our own system for the evaluation of our website and wheelchair documentation.

Among the most important features of any well-planned study is to have a clearly stated hypothesis. All of the studies that we examined had such a feature, which was key to guiding the research and avoiding researcher biases. For example, Kirby and White (2003) evaluated techniques used by health-care workers to fold and unfold wheelchairs. They hypothesized that techniques would be highly varied and that some would be ergonomically less desirable than

others. This provided a framework for the design of the study and guidelines for what data would need to be collected. Another study, by Hansen and Gunnarsson (2004), attempted to determine whether better maintenance on wheelchairs would produce fewer accidents. Again, a clear hypothesis was delineated, that increased wheelchair maintenance would result in a lower accident rate since wheelchair component failures are generally the result of improper maintenance rather than simple aging. In both of these cases, the design of the study was made simpler by having a distinctly testable hypothesis before any such work was begun. Furthermore, was vital to ensure that only one variable was changed as the research was conducted to avoid any confounding effects.

Methods for data collection are another important aspect of any clinical trial or study. The collection process must be properly controlled to provide a baseline for comparison with the group receiving some intervention. This is clearly illustrated in Coolen et al. (2004), in their evaluation of a wheelchair training system. In testing whether the training program would have a positive effect on the expertise of occupational therapy students, the authors separated the students into two groups, one that would receive the enhanced training program and another that would complete only the standard training included in the regular curriculum. For evaluation of the results, this study used a design very similar to our plans. It included a pre-test evaluation of the subjects before the study began and was followed by a post-test at the conclusion of the test period. Another study conducted by Kirby et al. (2004), examined a similar training system and its effect on direct care staff. This study also included a pre-intervention evaluation of the caregivers' skills, followed by the training program and a final evaluation. In this case, the study was case-controlled, with each caregiver serving as a control for him/herself. In cases where the

logistical realities of the study preclude having a formal control group, it is possible to obtain statistically valid results using such a system.

In many studies, blinding is used to prevent the intrusion of researcher bias into the data evaluation stage. If this is not possible, then other means are usually introduced to achieve a similar effect. For example, in the Kirby et al. (2004) study evaluating the wheelchair training system, the post-study evaluation was conducted by a researcher who was not directly involved with the training of the direct care staff. This sort of case-controlled clinical trial will be of the utmost importance to us in our work as we do not have the luxury of using multiple test sites as controls. While we did not have the additional personnel required to do a truly impartial evaluation of the results, we attempted to be as unbiased as possible in grading the pre-tests and post-tests. Research by Hansen and Gunnarsson (2004) also used a disinterested party to separate their participants into an active intervention group and a control group to avoid any researcher bias.

Furthermore, it is a common feature of most clinical trials to include an evaluation of the limitations and confounding factors associated with the study. For example, a study conducted by Fitzgerald et al. (2005) attempted to relate wheelchair durability with user satisfaction. After completing the statistical evaluation of the data, the study's authors concluded that the results may have been influenced by a lack of control over the specific types of wheelchairs used by the participants. They suggested that future studies could be more careful to include such information when controlling the results to produce a more statistically valid approach. Coolen et al. (2004) study of a wheelchair training program for occupational therapy students also included a careful evaluation of limitations. This study may have been confounded by the fact that all participants attended the same university. Also, the rapid decline in retained knowledge noted by

the researchers may have much to do with the relatively short period allocated to training. The study by Kirby et al. (2004) that evaluated a wheelchair use training program may have been compromised to a point by the coaching that wheelchair users offered their caregivers on proper handling technique.

These major parts of a properly conducted clinical trial were vital to any successful research that we conducted. From our examination of other similar studies, it was important to have a clear hypothesis, to collect our data carefully and in the most impartial way possible, and to evaluate and relate the limitations of our study in our final report.

Our research into clinical trials also showed the breadth of the research that has already been conducted with regard to wheelchair maintenance. Studies have evaluated the ergonomics of chairs (White & Kirby, 2003), accident rates and wheelchair inspections (Hansen & Gunnarsson, 2004), wheelchair durability and user satisfaction (Fitzgerald et al., 2005), and wheelchair training programs both for direct care staff (Kirby et al., 2004) and for students in the health care field (Coolen et al., 2004). Each of these studies shares common features with the others and provides a good model for properly conducted research.

With regard to the process of planning clinical trials, we investigated a guide written by J-P. Boissel of the Laennec School of Medicine (2004). While these particular guidelines refered to the planning of trials in a medical setting, much of the information was also applicable to our purposes. For any trial, the hypothesis to be tested must be stated before any data collection begins, a control group is important to distinguish whether the intervention produces any effect, the sample size should be sufficiently large to account for normal variations in data, and both the intervention and control groups should be treated exactly the same, with the only difference

coming in the single intervention component. Determining a hypothesis prior to the beginning of the trial is absolutely essential to an unbiased and scientifically valid result. Randomization of a trial and blinded data collection and analysis are important to the success of any large clinical trial. Prior to beginning any trial, a review of literature relating to past efforts is important in determining exactly what is to be tested and that the intervention is ethically and scientifically valid. This is more important in studies that are investigating completely new techniques. For our purposes, such a literature review was of less value as the Department of Mental Retardation already provided the official guidelines for what was to be done. Thus, our focus was primarily on determining whether the intervention worked and not on what the intervention was to be. Sample size also determines the power level of the study, its ability to support the hypothesis. Studies are generally not conducted unless they provide an 85% chance of detecting statistically significant changes in the outcome. Higher powers are achieved through increasing the sample size. In conducting a study with insufficient power, the risk exists that the study will conclude and be unable to reject the null hypothesis; that is, no knowledge is gained about the effectiveness of the treatment. Sample sizes are, however, often impractically large for the resources available. One way to deal with this issue is to increase the size of the expected effect. In this way, the study may still succeed if the effect of the intervention is large. However, this also reduces the power of the study. Finally, the entire system of data collection must be specified before the trial begins; improvisation leads to questionable results.

Admittedly, much of the information contained in references on study design methodology was overly complex for the relatively simple study conducted as part of this project. However, it was still important to recognize that sound, preplanned techniques are the

key to the reliability of any data collected from a trial, and that principle must be maintained even for small-scale trials such as this project.

Industrial Maintenance Studies

Industrial maintenance research revealed several important concepts that had potential applications to a DMR maintenance study. Several journal articles discussing maintenance studies in industrial settings all mention maintenance performance indicators (MPIs), which are measures that can be analyzed to provide insight into efficacy of a maintenance program. Additionally some authors recommend performing preliminary surveys of a study's subject to gain an understanding of its current maintenance situation and to aid in choosing the appropriate MPIs. Articles on industrial maintenance also note cautions for collecting and analyzing data, and suggest methods for compiling and presenting it.

Writings on industrial maintenance offer various insights into selecting MPIs. Aditya Parida's (2007) "Study and analysis of maintenance performance indicators (MPIs) for LKAB: A case study" emphasized the importance of using maintenance performance indicators that are meaningful to the whole of the organization for which they are measured. A set of indicators should be meaningful to the different levels of an organization's hierarchy. He even noted that other studies' research shows that "companies using integrated balanced performance systems" perform maintenance more effectively. Thus, care should be taken to choose maintenance performance indicators that have meaning to the whole of the business where maintenance is being measured.

When Parida (2007) selected his MPIs, he first evaluated the measures that his subject currently used, and then chose new indicators, which he deemed more appropriate and representative of the subject's interests. The existing MPIs that Parida (2007) considered were the belts availability, production speed, the number of stops and accidents, and the number of

environmental and quality complaints. He noted that these indicators were not used frequently enough and that they did not fully represent "effective utilization of the workforce and organizational performance." Based on his studies, he developed an improved system for measuring the plant's maintenance, which better balanced the interests of its different organizational levels. This multi-criteria maintenance performance measurement (MPM) framework includes the following MPIs: downtime, change over time, planned maintenance tasks, unplanned tasks, number of new ideas generated, skill and improvement training, quality returned, employee complaints and maintenance cost per ton (Parida, 2007). Note that these indicators are a mix of qualitative and quantitative measures.

In comparing the maintenance policies in "An evaluation of maintenance policies for flexible manufacturing systems: A case study," the authors, Vineyard, Amoako-Gyampah, and Meredith chose several MPIs. The first such indicator is equipment utilization, which the author defined as the percentage of time the machines are in use (2000). The second, machine downtime, is the duration of time that a machine undergoes any kind of maintenance. Next, the authors chose to measure throughput, which is the rate at which the system completes jobs. The last MPI they chose was "flow time," or the average time for the studied manufacturing facility to complete a job (Vineyard, et al., 2000).

In contrast to Parida (2007) and Vineyard et al. (2000), P. E. De Groote (1995) chooses MPIs that are all ratios in "Maintenance performance analysis: a practical approach." His reasoning for using ratios is that "efficiency is hard to appreciate in absolute value." De Groote (1995) divides these ratios into economic and technical MPIs. He further breaks down economic ratios into those that pertain to maintenance costs, those that are related to spare parts and those that are related to manpower. De Groote (1995) lists technical ratios as well, which he notes are

greater in number and variety than economic ratios. He uses a quantity called the overall equipment effectiveness (OEE) that is expressed as the product of an availability indicator, a speed indicator and a quality indicator. He lists a single availability indicator and speed indicator and numerous quality indicators. Note that De Groote (1995) divides the technical indicators based on whether they are of interest to the actual users of the equipment or their managers. He also stresses the importance of precisely defining the language of the indicators that one uses. An extensive list of MPIs, described by De Groote is shown in Appendix A.

In another article on industrial maintenance, "Maintenance scorecards: measure what you manage: scorecards offer an easy way to track and evaluate maintenance effectiveness," the author, Mike Cowley (2005) recommends MPIs such as backlog, machine downtime and uptime, work distribution, interrupts or breakdowns, the percentage of preventive maintenance work, the cost of maintenance compared to a machine's estimated replacement value and schedule effectiveness and compliance. Cowley suggests using some measure of how much money a maintenance program is saving, as well as various measures of a facility's inventory.

Thus, MPIs, which are qualitative and quantitative measures of the effectiveness of a maintenance policy are covered and chosen in several articles on industrial maintenance. All of the authors present sets of maintenance performance indicators, many of which are tied to fiscal concerns. The MPIs tied to operation time of equipment, i.e. the technical sorts of ratios such as those discussed by De Groote (1995) are more relevant to studying maintenance at DMR, since the main concern is the wheelchairs' users safely being able to operate their chairs. A study of maintenance programs at DMR would benefit from considering these MPIs used in industrial maintenance research and selecting those most appropriate.

Industrial maintenance research also suggests that one should conduct a preliminary survey of the study's subject. Such a study assists in choosing MPIs and provides the appropriate background knowledge of the equipment and processes being maintained. Both Parida (2007) and De Groote (1995) discuss such surveys. Parida (2007) uses his survey to understand the organization of his subject's personnel and to understand the details of the system he studies. De Groote (1995) details his survey less extensively, but emphasizes performing it efficiently.

Parida's (2007) "action research approach," which he uses to develop his set of MPIs, involves a series of interviews and an investigation of the conveyer belts, which were to be maintained. One of Parida's (2007) objectives in conducting this research was to gain knowledge of the conveyer belts' functions at a technical level. This involved studying the belts' "layout, design, capacity and drawbacks" and studying the belt system for "bottlenecks and critical spots." Another objective was to get a picture of the current maintenance program and to understand what the different levels of the company's leadership demanded from it. Determining this information involved interviewing thirty-eight different employees from various positions related to maintenance and noting aspects of the program such as, preventive and corrective maintenance, how the maintenance data are collected and any cleaning or inspection that is performed. Having ascertained the details of his subject's maintenance program, Parida (2007) completed a process, which he called "maintenance performance mapping." He argued that this two-fold process, which involves interviewing and a process study, is a crucial step in understanding a facility's maintenance program and is instrumental in helping the researcher get a grasp on the flow of maintenance work.

Like Parida (2007), De Groote (1995) points out that a maintenance study should begin with a "survey of the prevailing situation of the influencing parameters." They also agree that the

purpose of surveying the facility is to understand the maintained equipment and the details of the current maintenance program. De Groote (1995) argues that an effective maintenance survey should enable the auditors to acquire this information in a shortest time possible. Also similar to Parida (2007), De Groote's survey involves employees from different levels of the maintenance process. Additionally, De Groote (1995) recommends making a flow chart of maintenance program as a visual aid.

As discussed by Parida (2007) and De Groote (1995), maintenance studies should begin with preliminary surveys of the details of the process and equipment being studied as well as the staff. These studies provide important background and, as in Parida's (2007) case, assist in choosing MPIs. De Groote (1995) argues that a proper survey takes a minimum amount of time and that the surveyors should be able to develop a diagram of the flow of the process following the survey. These principles, though discussed in the context of industrial maintenance were useful in beginning a study of manual wheelchair maintenance at DMR facilities.

Various practical cautions about maintenance and maintenance studies can be taken from studies of industrial maintenance. De Groote (1995) and Cowley (2005) discuss the importance of ensuring the gathered data's integrity. In a maintenance study, it was important to take control precautions ensure that the data will be uncompromised.

Vineyard et al. (2000) and Cowley (2005) mention that caution should be taken in data collection to avoid bias. Cowley (2005) emphasizes that the gathered data must be objective and detailed. He warns that the savings measurement mentioned earlier are very subjective and recommends making realistic and conservative figures. Vineyard et al. (2000) in their comparison of different maintenance policies were careful to avoid any corruption or biasing in

their data. They chose a location that was typical of the type of manufacturing facility they were analyzing. Their location had the added benefit of having equipment failures being "monitored by both the machine tool manufacturer and the plant personnel." This balanced any tendency that the plant workers would have to blame the equipment manufacturer and vice versa for failures. The authors describe this as "a system of checks and balances…to ensure the integrity of the data." They note that since the plant had a corrective maintenance plan, that failure measurements at the plant result in a pure failure distribution. In other words, it represented the equipment's natural rate of failure because no preventive maintenance prolonged its function. Since they were interested in the failure distributions for the equipment, this setup was optimal for ensuring that this information was genuine. In performing a maintenance study, Vineyard et al. (2000) and Cowley's (2005) notes on integrity should be kept in mind.

The last topic of interest discussed in industrial maintenance studies is the collection, analysis and presentation of MPI data. Cowley (2005) and De Groote (1995) both discuss this subject and recommend computerized storage of the data as well as visual representations thereof to assist the maintenance team in tracking their progress and requesting various resources.

Cowley (2005) recommends gathering the data in a "Computerized Maintenance Management System." As for analysis, he recommends performing a "Pareto analysis of interrupts and downtime." This sort of analysis essentially involves seeing if particular pieces of equipment cause the majority of maintenance problems. According to Pareto, twenty percent of the equipment will cause eighty percent of the problems. Cowley (2005) suggests "maintenance scorecards" to assist in maintenance management. This scorecard essentially reports on various MPIs and displays them through figures and charts. He suggests using it for determining the maintenance program's progression towards its goals and to assist in requesting funding, etc.

De Groote (1995) offers similar advice to Cowley's (2005) concerning the storage and presentation of maintenance data. He recommends a "centralized system for data assessment" even for smaller companies. Concerning data analysis, De Groote (1995) recommends taking advantage of charts of the ratios to monitor for emergencies, aid in analysis and presentation of the data and to reinforce decisions concerning the maintenance program. He also notes that another part of the purpose of such a monitoring chart is to gain "a precise idea of the performance of maintenance." Thus both De Groote (1995) and Cowley (2005) suggest implementing electronic storage of maintenance (such as a database), and charts and figures observe a maintenance program's progress.

Industrial maintenance reveals several important aspects of maintenance studies. The first is the choice of MPIs. Various MPIs are presented and discussed. A maintenance study at DMR would profit from considering each of these MPIs and choosing those most relevant to DMR's situation and concerns. As discussed earlier, the volume of financial measures will have less utility than those that relate to the usability of the equipment. In a study focused on comparing maintenance policies, choosing MPIs would be a key step. Another important consideration was the concept of a preliminary survey. Such a study would be instrumental in understanding how wheelchairs are maintained and the typical flow of maintenance procedures. It was also important to take care to ensure that the data collected was unbiased and impartial, as discussed in several of the industrial maintenance articles. Finally, as recommended in the research, some sort of electronic storage, such as a database or spreadsheet and the use of graphics and figures to represent the data would also be useful in a DMR maintenance study. In a study focusing on comparing maintenance policies, these points from industrial maintenance articles would indeed be helpful.

User Manual Design

We also examined a reference entitled *How to Write a Usable User Manual*. One of the major recommendations from this guide was that manuals be written so that the content is suitable for the intended audience. Instead of combining all possible information into one document, it is far clearer to divide this information into smaller pieces, directed to the people who need it (Weiss, 1991, p. 19). Manuals must also be accessible; the reader should not have to search through the text to complete a single task; redirecting to other sections should be minimized. Finally, readability is critical; the manual must be engaging and understandable to the target audience. When writing a manual, it is also important to verify that it may be updated easily; if something in one section is changed, the rest of the manual should be revised to incorporate that change. Consequently, a system must be devised to support this revision (Weiss, 1991, p. 37). All manuals will need editing to produce a usable result. Errors generally fall into the categories of mechanics, appropriateness of language, clarity, accessibility, and urgency. The first deals with simple grammar and spelling. Manuals, however, should also strive to eliminate unnecessarily long and/or awkward phrasing, overly complex descriptions of tasks, jargon, and phraseology that may be misinterpreted. Urgency refers to making the manual engaging and interesting to read, through the use of graphics, varied sentence structure, and good word choice (Weiss, 1991, p. 147). Among the most important errors to avoid is using too many words, or "showing off" with words that are not necessary to convey the idea. By the same token, using too few words also makes reading difficult. The goal is to create a manual that reads easily, with language that flows well and that may be understood as quickly as possible. Misplaced modifiers is one problem that can produce confusion on the part of the reader. When writing complex ideas, it is helpful to place the most important part of the sentence near the end, as this is the part

that is remembered best (Weiss, 1991, p. 150). While passive constructions can be awkward, they are sometimes useful in moving the critical parts of sentences to the best location. Page layout is also important. Wider margins, varied type styles, more graphics, and clear section breaks all help the reader get oriented in the manual (Weiss, 1991, p. 159).

The text also discusses several ways of quantitatively measuring readability. For example, for a manual aimed at lower level employees, the Fog index, a test for readability, should be no higher than 8 (Weiss, 1991, p. 155). Two common tests are the Fog index and the Clear River Test. The Fog index is computed by the following formula:

"Fog Index = 0.4 x (AWS + %DW)"

Where AWS is the "average words per sentence" and "%DW," the percentage of difficult words, is the percentage of the writing that is made of words with more than three syllables. According to Emmanuel Katzin (1985, p. 12), the AWS and %DW are computed on samples of 100 – 200 words. Table 1, which was adapted from Katzin's book, explains the meanings of different values for the Fog Index. Anything above the danger line may not be suitable for documentation for a mass audience.

Table 1: Fog Index[1]

FOG INDEX		
Fog Index	Reading Level by Grade	Reading Level by Magazine
17	College Graduate	
16	College Senior	No popular
15	College Junior	magazine
14	College Sophomore	this difficult
"- - - - - - - - - - - - - - - - Danger Line - - - - - - - - - - - - - - - - - - "		
12	High School Senior	Atlantic Monthly
11	High School Junior	Harper's
10	High School Sophomore	Time
9	High School Freshman	Reader's Digest
8	8th Grade	Ladies Home Journal
7	7th Grade	True Confessions
6	6th Grade	Comics

The other test that Katzin (1985, p. 13) mentions is the Clear River Test, which compares words per sentence, words per paragraph, syllables per 100 words, and words per punctuated pause (which excludes marks between listed items) to a standard that is "acceptable for business writing." This standard is based on an average of 25 words per sentence, 75 words per paragraph, 150 syllables per 100 words, and 12 words per punctuated pause (Katzin, 1985, p. 14). As far as our writing was concerned, this made the Clear River Test less relevant than the Fog index. As

[1] See Katzin (1985, p.15) for the original table.

our preliminary research indicated that a business level of writing would be inappropriate for the direct care staff, this quality standard would at best serve as an upper limit. The Fog index would give us a more precise estimation of the level at which we are writing. Thus, these readability measures, which Katzin (1985, p. 14-15) suggests, would be pertinent to our development of a maintenance handbook that is tailored to the direct care staff's needs.

How to Write A Really Good User's Manual, by Emanuel Katzin (1985) makes several other key points about manual writing, which are relevant to this project. He emphasizes the importance of understanding the manual's users. Since readability is necessary for a user's manual, he suggests different tests to determine if the document's style of writing is at the right level for its audience. Katzin also discusses structure of a manual, noting the importance of its role as a reference, and the need for a properly designed table of contents and glossary. Finally, Katzin recommends supplementing the manual with a training program.

In order to "'communicate' in the right perspective" with the manual's users, Katzin (1985, p. 5) argues that is important to understand them. One aspect of this is recognizing their organizational role. It is important to understand their jobs and to understand their hierarchy (if any), especially if there is to be any restriction of the manual's information within the group. In our case, this meant understanding the direct care staff's tasks and their supervisors' tasks, and what kinds of repairs some or all of them would be allowed to perform (Katzin, 1985, p. 5). Additionally, it meant considering whether or not we should design multiple versions of the manual. The author recommends noting within the manual where the reader can obtain the omitted information if different modules or versions are to be written, and recommends keeping a complete set of all of the manuals on hand (Katzin, 1985, p. 6).

According to Katzin (1985, p. 8) another aspect of understanding the manual's user, is recognizing what information he needs to obtain by reading the manual. He argues that since the manual is "a tool and a reference *for* that User group," that it must be tailored to their "needs and requests on how they should perform their work." Our user manual should be able to show the direct care staff how to identify and report problems and how to repair the wheelchairs according to the repair staff's expectations for them. Thus, it was of prime importance for us to know in detail what the repair staff expected from the direct care staff, so that we could write a manual that effectively filled this gap in their knowledge. Katzin also recommends meeting the manual's users "to question, suggest, determine and agree" on their needs. This strategy was useful in determining what the direct care staff's computer skill level or familiarity with fasteners is.

As a final noteworthy point that Emanuel Katzin (1985, p. 9) made about understanding the manual's user is that the writers should become familiar with the users' "professional background." This includes knowing their "general *education level*," their degree of experience with the manual's subject, their computer skills and their turnover rate. Katzin (1985, p. 10) notes that if the amount of previous knowledge is limited and an "on-the job training" program is implemented, one will want to understand the manual's role in the training. He also comments that it is important to determine how acquainted they are with the "concepts and terminology" involved with the computer use. In our case, writing an appropriate manual for the direct care staff demands that we determine their reading level and their computer skills to choose the proper language level and amount of explanation required. Since a high turnover rate was indicated, it was useful to have an understanding of how the manual will be involved in training new hires.

In addition to his advice about knowing the manual's users, Emanuel Katzin (1985, p. 21) offered practical advice about writing a readable manual. He warns against using long words, since "they make the reader work harder". To Katzin (1985, p. 19), "simplicity and directness are prime virtues for informational and instructional writing." To back this point, he presents research, which shows the strong inversely proportional relationship between the average number of words per sentence and the percentage of comprehension. Though Katzin (1985, p. 31) recommends having short sentences (approximately 20 words), he warns that "variety…is the spice of writing" and therefore "every sentence should not be the same length" to prevent the manual from being too dry. His last practical caution regarding word count is that even reasonably sized sentences can communicate poorly. In addition, if describing something becomes too cumbersome, he suggests using graphics. Katzin's (1985, p. 11) advice that graphics, short sentences, short paragraphs and "simple, direct, and crisp" language are the key to a lucid manual will be important to apply in rewriting the current maintenance manual.

Concerning the structure of a user's manual, Katzin emphasizes the importance of a table of contents and offers advice about other sections, such as the glossary. Since the main role of a user's manual is serving as a reference, Katzin (1985, 36) argues that the table of contents is the most important section. He adds that the table of contents should have a "logical and functional layout" to ease finding a subject within it and a "simple but adequate numbering system." Like his recommendations for other aspects of a user's manual, simplicity is of the utmost importance. In addition, following the table of contents, there should be a short introduction (less than a page and a half) explaining the purpose of the material being covered and the manual and providing an overview of its information (Katzin, 1985, p. 42). Katzin (1985, p. 42) also describes the importance of having a glossary. A glossary helps both the reader and writer of the manual, since

the reader will be able to learn the vocabulary of the job that he or she uses the manual for and the writer will not have to reiterate explanations of terms. Other benefits of including a glossary are that the manual becomes more readable, as definitions are not dryly repeated, and the glossary makes the manual more useful as a reference. These practical suggestions, like those about readability were also useful to apply while revising the manual.

A final interesting idea from Katzin's (1985, p. 9) guide on writing a user's manual is the notion of having a supplementary training session. He points out that having a classroom orientation has been statistically shown to decrease the amount of personnel turnover. As our manual was written for a job, which, according to our research has a high turnover rate, this potential benefit could not be overlooked. Katzin (1985, p. 235) notes that the main purpose of such a training session is "to introduce…the new manual which you are presenting." A major objective of a training session is to help acquaint the user with the manual's organization so that "he can efficiently and quickly find the information he needs." If any technical details are to be included, Katzin suggests having a technical expert conduct the training and suggests that the level of technical depth be noted. As for the setup of such a training session, the author recommends a seminar or classroom format to inspire interest in the class and to allow the writers to ensure that the students comprehend the material presented. In addition, the presenters should use as many visual aids as they can create comfortably and should "try to involve the students in solving problems and assignments" (Katzin, 1985, p. 235). Katzin (1985, p. 237) warns that a major pitfall of a training session is teaching material that the audience already knows. Indeed, it would be important to avoid accidentally losing the audience's attention by making this mistake. Having a segment of a training session, which focuses on explaining how to use the revised manual, improved our program's efficacy. The author's concept of a classroom

styled program involving visuals and interaction with the audience was an excellent way to familiarize the direct care staff with the handbook.

Thus, *How to Write a Really Good User's Manual*, by Emanuel Katzin offers relevant guidance for developing and implementing our handbook. Katzin stresses the importance of knowing the manual's audience well, with respect to the knowledge that they will require, their level of education and background and internal organization. He offers practical tips on writing effectively, and appropriately for the intended audience. For instance, if the background of the audience indicates that most of them have no education beyond high school, it would be a mistake to write something at a college reading level. To test the writing to make sure that it is at the right level, he points to methods like the Fog index. In addition, the simplest language, with regard to structure, word choice and wordiness should be employed. The author offers advice for the layout, such as having a simple, well-organized table of contents and a glossary of the terms. The glossary is especially effective in improving the flow of writing, by not having to reiterate definitions. Finally, he advocates developing a training program to complement the manual and fully realize its usefulness. To conclude, applying Emanuel Katzin's concepts aided us in producing an excellent handbook for the DMR staff.

Survey and Interview Design

The vehicle by which this IQP gathered data and feedback regarding the performance of the web-based manual wheelchair repair content was from data generated from surveys and interviews. It was important to seek and gather the appropriate target information that could be effectively analyzed for results. The target audience for these questions was DMR's direct care staff, their supervisors, and various wheelchair vendors. There were numerous sources available

dealing with survey and interview design that all share parallel information. Meaningful results from this IQP were dependent on the responses that were received making it critical that questions were chosen carefully and appeared in language the intended audience would be comfortable with.

An article from the E.R.I.C. and A.E. staff in the *Practical Assessment, Research and Evaluation* journal entitled "Designing Structured Interviews for Educational Research" states three main criteria for writing appropriate questions ("Practical Assessment," 1999). These three general guidelines are the essential rules that form a baseline for survey study design.

1. Relevant questions must be directly related to the purpose of study and must give the type of data that is sought.
2. Questions must be tailored to the intended audience.
3. Questions must be easy to answer and must not cause the respondent to become embarrassed or to have to look up records.

Different types of questioning styles including open-ended questions, yes or no answers, and fill-in-the-blank will yield different types of answers. Open-ended questions tend to be too unstructured and take more time to decipher the results. Yes or no, true/false questions are better suited for gathering factual information quickly as well as narrowing down the choices for the respondent ("Practical Assessment," 1999). In an article entitled "Smart Survey Design," *SurveyMonkey* recommends choosing questions that can be answered within a short amount of time and without much effort. Longer questions and surveys tend to tire the respondent which will make them try to get through the questions as quickly as possibly therefore running the risk of receiving information that is not their actual thoughts. Double-barreled questions, which

contain more than one topic that can be split up, are another danger to be aware of ("Smart Survey," 2007).

Leading questions and built in assumptions are yet another plague of survey and interview design. It is often easy to slip into a mode of biased questioning to get the answers that you want to hear. Careful word placement and simple objective questioning will help to avoid these conditions (Doyle, 2006). Doyle also offers some general pointers to check as reference for each question. He recommends thinking about the possibility of how the question can be misinterpreted and in how many different ways it could be answered. The questions should be clear enough so that the individual automatically knows what kind of answer would be appropriate.

Question grouping and ordering is another important organizational piece of designing effective surveys. Related topics can be sectioned and indicated by headings. All questions and any topic grouping should be rank ordered from most important to least important (Doyle, 2006). Doyle also recommends starting with a few easy to answer questions dealing with the big issue pertaining to the interview or survey to gain the respondents attention. Making the organization of the questioning obvious by sectioning or adding an introduction that explains the survey is another helpful way to motivate the respondents. Leaving closing comments that thank the respondent for his or her time is a way to ensure that the user knows his or her contribution is appreciated ("Smart Survey," 2007). From *Qualitative Research Methods for the Social Sciences,* Berg reports that the first few questions should be non-threatening and should allow the interviewer to become comfortable with the content (Berg, 2007). SurveyMonkey suggested adding a few simpler questions at the conclusion of the survey to again regain the confidence of the respondent before closure ("Smart Survey," 2007).

Gathering the necessary data and reporting it from such methods as surveying and interviewing requires rationalization with some kind of method to convince the reader of your findings. Doyle explains a five step process of response analysis consisting of a section dealing with details of the respondents, the sampling process (pre-selected in the case of this IQP), a section telling the reader about the design and construction of the survey/interview, the implementation procedure, and any limitations and constraints that were involved (Doyle, 2006). Various statistical analysis methods can be used to analyze the validity of data. Determining an appropriate statistical analysis method is just as important as selection of the right kinds of questions to ask.

Questioning methods such as surveys and interviews put people on the spot for answers. The goal of a good survey or interview design is to make the respondent as comfortable and as least intimidated as possible. Using short and to the point questions, organized in a meaningful manner, will avoid confusion and yield more specific results. Accomplishing these tasks will allow the person to answer honestly and give the data seeker a more reliable input. This IQP required a solid study design in order to get dependable data analysis to support its purpose. It was especially critical in this case to design efficiently given the timeline constraints within the schedule.

Project Scope

This project consisted of three distinct phases that were necessary to produce usable data for the Department of Mental Retardation. The first phase consisted of revising the documentation that had been created by a previous IQP group (Trimby et al., 2004) and creating a website based on the template developed by another WPI IQP group (Young & Holmes, 2001). The documentation was extensively revised to make it technically simpler and to provide only that information that was required by the direct care staff at DMR's facilities. Furthermore, we streamlined the protocol used by the direct care staff when wheelchair problems are encountered. All of this information was then presented on a website designed to be easily navigated and largely self-explanatory.

The second phase of the project was devoted to the evaluation of this documentation's effectiveness as a reference for direct care staff. To that end, we designed a study to be conducted at several DMR and DMR-contracted group homes with the participation of direct care staff members. This study required that we collect data about the improvement of the staff's performance in several major areas of wheelchair knowledge, including terminology, mechanical knowledge of fasteners and tools, problem reporting protocol knowledge, how to collect pertinent wheelchair data, and how to diagnose wheelchair problems. To that end, we created both written and practical tests involving a test wheelchair to evaluate the staff's progress. These were administered at each participating DMR facility.

The final phase of the project was data analysis. Consulting with Professor Joseph Petruccelli of WPI, we developed a statistically analysis approach that enabled us to determine whether any of our results were statistically significant. Due to our small sample size and

unpaired data set, Fisher's Exact Test proved to be the best option.

Methods

Documentation

The first task before evaluation of the documentation could begin was to rewrite and revise the existing documentation so that it was clearer and included a more limited set of instructions for the direct care staff and supervisors. The previous IQP groups had produced a website-based maintenance manual that included troubleshooting and repair tasks that were beyond the practical resources of the individual group homes. For example, we could not expect the direct care staff to replace upholstery or change wheel bearings. Furthermore, if major repairs are not completed by qualified repair technicians, the chair's warranty is at risk of being voided. Consequently, we focused only on the most basic of repairs that involved simple hand tools. Beyond this, the other major focus of the website was to develop a streamlined protocol for reporting problems and to serve as a reference for wheelchair terminology. For inspection, we choose to use the checklist that was developed by the previous IQP group with some relatively minor adjustments to keep the language as simple as possible and to improve its clarity (Trimby et al. 2004). We added several new labeled diagrams of wheelchairs and reduced the number of steps required to inspect each chair.

We extensively rewrote the troubleshooting section to make it less technical and to ensure that all repairs could be completed with a limited set of tools. This tool kit consisted of flathead and Phillips screwdrivers, metric and English allen wrenches, an adjustable wrench, and needle nose pliers, all contained in a toolbox. These kits were created and then distributed to each home. In addition to the checklist and troubleshooting sections, we added a new glossary to the website, drawing the terminology largely from the ISO standard TC 173/SC 1 N 365

published in 2002, but supplemented by terms that are actually in use by staff and repair technicians. The definitions, however, were rewritten entirely to avoid the use of overly technical language and medical references. We linked this glossary to additional labeled diagrams showing the parts in question; these were drawn from McMaster-Carr and the wheelchair owner's manuals for the four most common chairs. We also obtained photographs of these chairs, the Quickie Iris, 2, and LX and the Invacare 900 series, and labeled all visible parts with the correct terminology.

In addition to developing reference material for the staff to use as they inspect the wheelchairs, we wrote a set of simple instructions to follow in the event of a problem with a wheelchair. These instructions divide the manual into two parts, one for the supervisors or designated wheelchair repairperson and the other for all direct care staff. The designated person was chosen on a volunteer basis by the individual homes. The instructions for all staff incorporated the advice from DMR repair technicians and common sense repair protocols. In the event that staff discover loose wheelchair pieces on the floor, they should be sure to collect all pieces that they find and report the problem to their supervisor. To that end, we developed a repair form for internal recordkeeping that can be used to keep track of repairs and vital wheelchair information such as the model number and serial number. The supervisors then could use the troubleshooting section of the website to determine if the problem warranted a call to the appropriate vendor. Guidelines for communicating with the vendors to ensure prompt and reliable service are also available from DMR. Approval for this documentation was obtained from DMR's representatives. The new flow of information using the standard problem reporting protocol is shown in Figure 2.

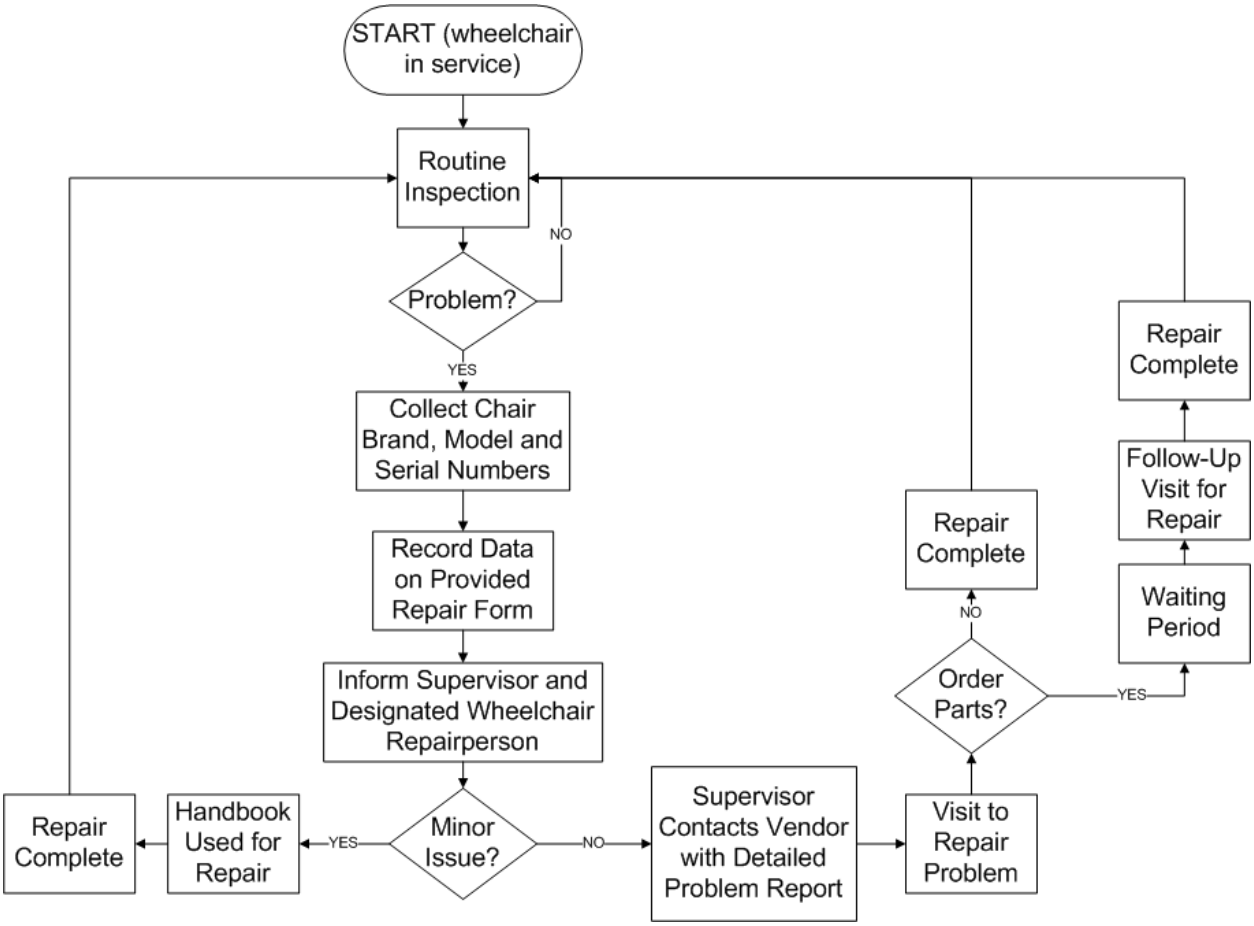


Figure 2: Planned Process Improvements

Since this pilot study is being conducted in a limited number of DMR facilities, and no employees with low vision are involved, we elected to update the previous website instead of building a new one based on the required accessibility standards. While this website is not accessible, it did enable us to complete our initial test of the documentation's effectiveness and determine whether any major changes in the website structure were necessary before a fully accessible site is created. Given the relatively short time available to complete this project, we decided to delay conversion to a fully accessible form and to host the website on WPI servers as opposed to state assets. The website design that we chose was produced by the first IQP group to

work with DMR (Young & Holmes, 2001). We chose this site because it was already Bobby-approved, an older website accessibility verification tool. It was also technically simpler to modify for our purposes.

Test Program

The actual implementation of the test program consisted of several distinct phases. The first was to collect baseline data to gather information as to the level of the staff's proficiency without our new documentation. This evaluation consisted of an anonymous written pre-test that assessed their knowledge of wheelchair nomenclature (questions 1-14 shown in Figure 3), tool recognition (question 15 shown in Figure 4), mechanical knowledge of tools, tool use, and fasteners (questions 16 – 19 shown in Table 2) and proper repair protocols (questions 20 – 22 shown in Table 3). We elected not to record names during the course of study. It was unlikely in some cases that all members of the staff who took the pre-test would be available to take the post-test, and we believed that the staff would feel more at ease if personal information were not collected on the forms. In addition, we intentionally damaged a wheelchair with the assistance of the Monson Developmental Center and asked the staff to identify as many problems as they could. They recorded their observations on our standard wheelchair repair form (shown in Figure 5) which we graded based on its correctness. Any problems that the staff identified that we did not create were ignored as extraneous. A rubric was also used to guide the grading of the written tests. We graded the staff only on the problems we intentionally created. The grades from both the pre-test and the repair form were entered on an Excel spreadsheet. Following this initial evaluation, we presented the web material and checklist to each shift at each of three facilities. We returned to each facility multiple times to address the first, second, and third shifts during their normal working hours. Approximately five staff members participated from each shift at

each facility. These brief seminars required approximately 30 minutes to complete and included a tour of the website and its key features. We explained where the staff could find troubleshooting information, the wheelchair terms glossary, the maintenance checklist, and general cautions. During the seminar, many of the answers to questions on the pre-test were explained.

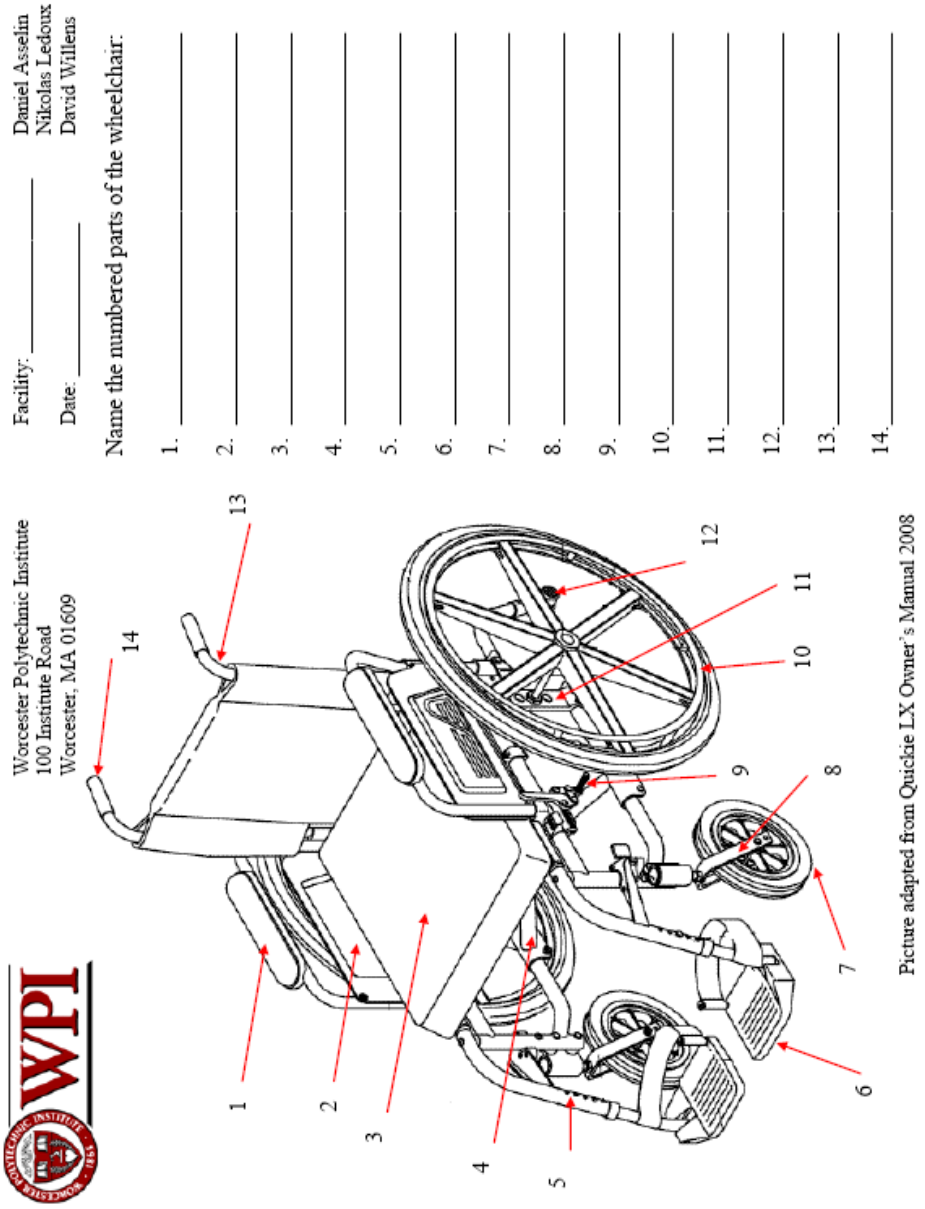


Figure 3: Wheelchair Nomenclature Test Questions

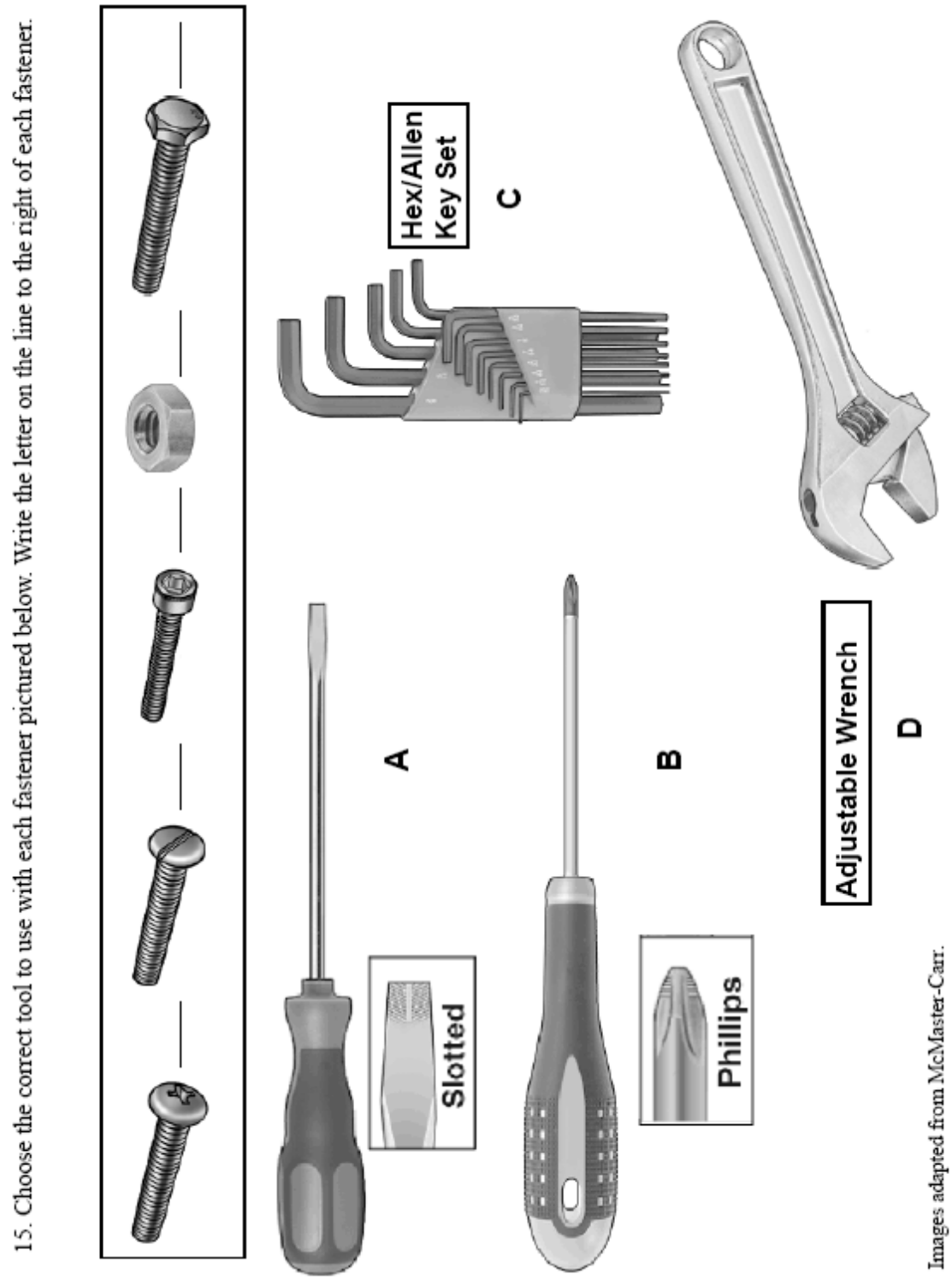


Figure 4: Tool Recognition Test Questions

Table 2: Mechanical Knowledge of Tools, Tool Use, and Fasteners Test Questions

16. If you are missing a screw to an arm support, where could you look on the wheelchair to find out what kind of replacement screw is needed?

17. What are the two measurement systems that are used to identify fasteners?

18. Can you use a fastener from one measurement system in a part designed for the other measurement system?

19. If after trying to start a screw it gets stuck, what should you do?

Table 3: Repair Protocol Test Questions

20. If you find wheelchair fasteners or parts lying on the floor, what should you do with them?

21. Where should you look to find the model number and serial number of a wheelchair?

22. What is the first thing should you should do if you notice a problem with a wheelchair?

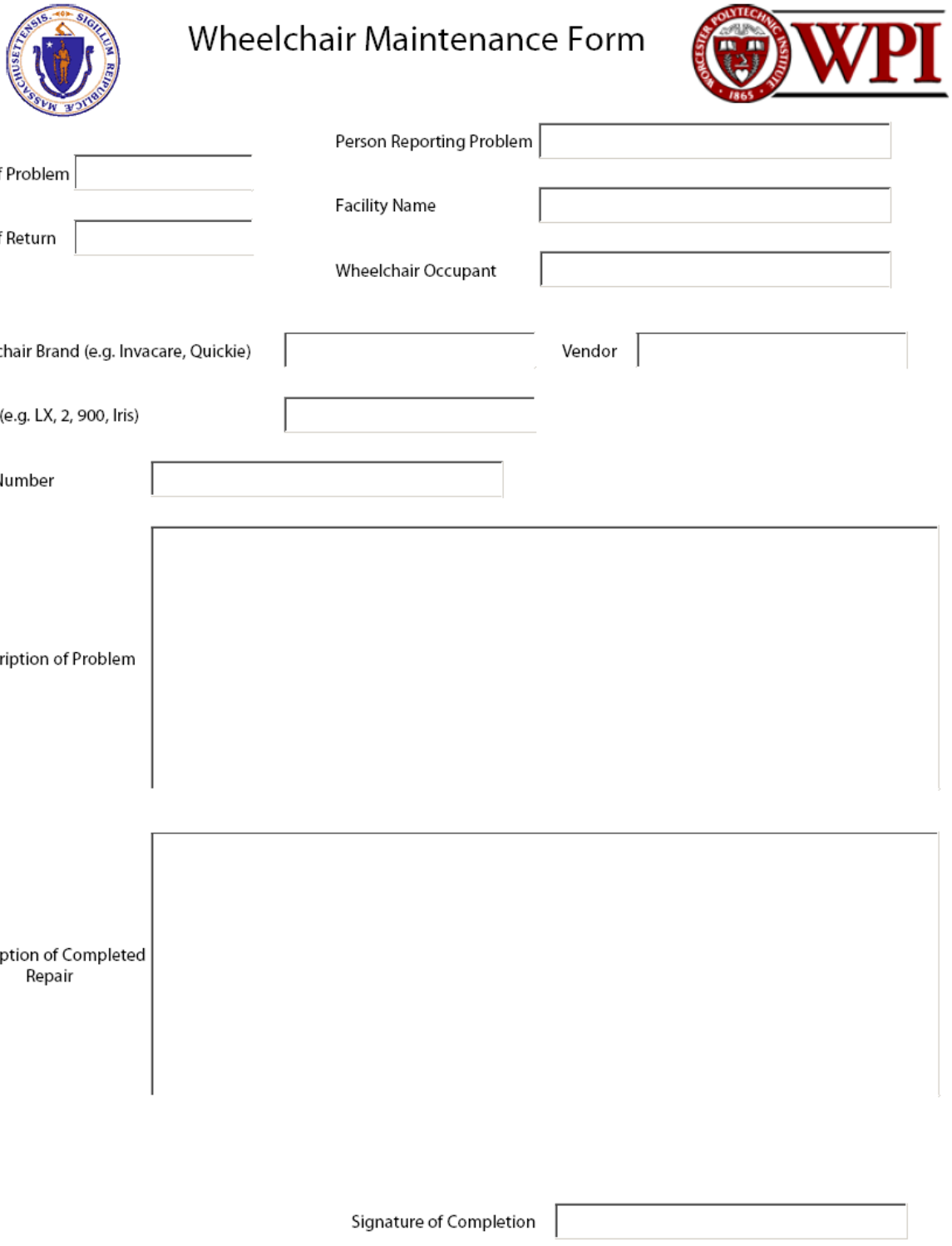


Figure 5: Wheelchair Maintenance Repair Form

The participating facilities included one run by DMR itself, located 197-199 Providence Street, Worcester, MA, and two managed by the Seven Hills Foundation, located at 153 Delawanda Drive, Worcester, MA, and at 51 Winslow Avenue, Leicester, MA. Our fourth home, supervised by DMR and located at 30 Veterans Parkway, Uxbridge, MA, began late in the study due to scheduling difficulties related to a death at the home. During the presentations we described the features of the website and where all of the information could be located. We also described the recommended inspection intervals to be used with our checklist. We provided printed copies of the checklist. At these presentations, the homes received the toolkits and a journal to be used to record any problems they encountered with the website or suggestions for improvement. We checked this journal weekly for any comments. Access to the website was coordinated to give each home access via the Internet if possible or via a CD if not.

After the homes were given the opportunity to familiarize themselves with the new documentation, we returned the damaged wheelchair to each facility with the same problems as before. They were again asked to inspect the chair, this time using the checklist, and to fill out another repair form. Repair forms with an attached checklist and directions were provided. This provided an opportunity to evaluate the progress of the staff with some exposure to the new documentation.

At the conclusion of the study, we administered the post-test. The post-test consisted of the same questions as the pre-test with the addition of subjective questions relating to the homes' actual use of the website and whether they encountered any difficulties in integrating it into their wheelchair maintenance routine (questions 23-28 shown in Table 4). We also returned the damaged wheelchair to each facility for a post-inspection. The wheelchair included problems that were different from those initially presented. We also collected the repair forms that were

filled out during the course of the study. Finally, we interviewed representatives from Ultimate Mobility of 1158 Main Street, Worcester, MA to get their impressions as to the staff's progress.

Table 4: Website Use Test Questions

23. What information should you gather prior to organizing a wheelchair repair besides a description of the problem?

24. If you are unsure of the proper name of a certain part or are unsure of what it is, what can you use to help you?

25. If a foot rest or arm support adjustment has gotten stuck while trying to move it, what is the first thing you should try?

26. What should you do if a resident complains about hard and sharp objects poking into his or her arm support?

27. If you see dirt or grime building up on the wheelchair's moving parts what should you use to clean them?

28. If when following the maintenance checklist you discover problems how should you document them?

Analysis

With the data collected, we proceeded to a statistical analysis of the grades developed from the pre-test and post-test. We consulted with Professor Joseph Petruccelli of the WPI Mathematical Sciences department. Because we did not collect personal information on the tests, we had a data set that was not paired. To analyze these data, we used Fisher's Exact Test.

The Fisher test is a permutation test that is useful for small sample sizes. It yields an exact probability that the null hypothesis is true. For our study, the null hypothesis is that the results of the second test are independent of those of the first and that our program had no significant effect. Our alternative hypothesis is that our program had a positive effect on the outcome of the second test. We elected to use a standard 0.05 p-value test for the purposes of establishing statistical significance. For analysis purposes, we divided the data into three distinct subgroups: wheelchair terminology, mechanical knowledge, and repair protocol knowledge. Several questions on the tests dealt with each of these three areas. Analyzing the results question-by-question did not produce any useful information. We also examined a total score for each home. Each home was analyzed individually to allow for differences among the facilities.

The Fisher test was also applied to the wheelchair maintenance repair forms that the staff filled out upon each inspection. These forms were divided into two sections: one for the correct gathering of pertinent wheelchair information including the brand, model number, and serial number, and the other for correctly identifying as many problems as possible. The test wheelchair was brought to Providence Street four times and to Delawanda Drive and Leicester three times during the course of the study, approximately every two weeks. All tests subsequent to the first one were completed with the aid of the pre-printed inspection checklist and were thus compared with the Fisher test to the baseline data of the first inspection.

In the planning of the study, we had intended to implement our program at four sites, the three previously described and a DMR-run facility in Uxbridge, MA. However, the test program at the Uxbridge facility did not begin on time and was delayed to the final two weeks of the project. Furthermore, fewer staff were available to participate in the program, yielding a smaller sample size. Consequently, the results from Uxbridge are less useful than those from the facilities that completed the entire program. We focused our analysis primarily on the three facilities that fully participated in the study.

Results

After tabulating the raw data and analyzing the results using Fisher's Exact Test, we were able to draw several important conclusions about the efficacy of our material. Overall, each facility showed improvements in at least one of the five major areas of evaluation. Again, these areas were wheelchair parts terminology, basic mechanical knowledge, knowledge of the correct problem reporting protocol, the collection of brand, model number, and serial number information, and the diagnosis of problems on our test wheelchair. The areas of improvement were mixed across the four facilities.

On the post-test website survey, participants were asked to report the number of times that they used the website and checklist and whether the documentation was sufficiently clear and easy to understand. Of the 32 participants in the post-test, only three indicated that they had used the website at all, and these three had only used it once during the project. This was disappointing to us, as we had expected the staff to take their own initiative in making the website a part of their normal work routine. To encourage this, the test wheelchair program was designed to require use of the website for inspection and for determination of the correct terminology. However, after the second visit with the test wheelchair to Providence Street, we noted that the results were largely identical to the first visit. We concluded that the staff were not using the checklist. As it became clear that the website was not being used to its fullest extent, we elected to modify our procedure for using the test wheelchair. We attached copies of the checklist along with explicit instructions to use the checklist to each copy of the repair form that we distributed to the facilities. Following this, we noted more dramatic improvements in subsequent visits.

Furthermore, the staff indicated a preference for printed material over web-based information. All respondents to this question, 19 of the test-takers, wanted hard copies. Twelve preferred to have printed material only, while seven preferred both online and printed material. Thus it is clear to us that an exclusively online solution will not be amenable to the current situation.

Among the four facilities, Providence Street showed the most improvement, ameliorating their scores in four of the five areas of interest. We attribute some of this improvement to an unexpected incident: the third-shift supervisor had a vacation scheduled for a week in the middle of our test period. Because the supervisor is the only staff member with a key to the computer desk, it would have been impossible for anyone else to access the website during this period. This event forced us to provide printed copies of the entire website to the Providence Street facility. The greater availability of the documentation likely encouraged the staff to use it.

At the other three facilities, the improvements are likely due to the repetitive use of the checklist during the inspections of the test wheelchair and our introductory seminar. Because the website was not extensively used, we can attribute the improvements only to these activities. Supervisors at all facilities expressed the view that the staff were much more aware of wheelchair maintenance issues, which may also have contributed to higher scores.

The results of our analyses of the data are presented in Table 5. For full results, see Appendix G. The values listed in the table are the probabilities that the results from the two tests are independent of any intervention from our program. All values were generated by Fisher's Exact Test.

Table 5: Probabilities of Statistical Independence of Pre-test and Post-test

Facility	Terms	Mechanical Knowledge	Protocol Knowledge	Problem Diagnosis	Data Collection	Overall
Providence	<0.001	0.007	0.092	0.039	0.017	<0.001
Delawanda	0.069	0.067	0.009	0.819	0.016	0.017
Leicester	0.002	0.173	0.024	0.489	0.101	0.002
Uxbridge	0.048	0.232	0.272	0.383	0.500	0.007

Note: Underlined values are statistically significant.

In the above table, Terms refers to the correct wheelchair parts nomenclature as tested on the pre-test and post-test. The next categories, Mechanical Knowledge and Protocol Knowledge, were measured by the remaining questions on the written tests. Finally, Problem Diagnosis and wheelchair Data Collection were measured by inspections of the test wheelchair. Problem Diagnosis was measured by the number of correctly identified problems according to our rubric. Finally, Data Collection refers to the correct gathering of wheelchair brand, model number, and serial number on the repair forms. The numbers in the table are the probabilities generated by Fisher's Exact Test. Those which are underlined are less than 0.05 and therefore statistically significant.

All of the facilities showed improvement when measured in the aggregate over all five categories. The weakest areas of improvement were mechanical knowledge and the diagnosis of problems on the test wheelchair. The greatest improvement was in wheelchair terminology,

where three of the four facilities improved. We also analyzed wheelchair terminology using the responses on the wheelchair repair forms following each inspection. In determining the correct use of terms, we counted any correct term listed on the form, regardless of whether the indicated problem was correct. Comparing the terminology on the forms used during the last inspection attempt with those used during the first using Fisher's Exact Test yielded no statistically significant results. However, we believe this to be the result of small sample sizes for some of the inspections at each facility. We did notice better usage of terminology on later repair forms.

As an informal measure of the amount of website usage, we added several additional questions (23-28 shown in Figure 4) that asked specifically about the website and information contained on it. Given the limited website usage during the project, the staff's scores in this area were predictably low. The questions could only be answered correctly if the website had been visited. For questions relating to where information is found on the website and to troubleshooting procedures, few participants at both Leicester and Delawanda Drive answered correctly. All scores were approximately 50% or less. At Providence Street, scores on questions related to finding information on the website were comparable (41%), but staff did succeed in identifying the correct troubleshooting procedures (69%). A majority of participants at each facility answered a question about wheelchair cleaning correctly, likely because this is already an established routine at each home. The correct cleaning procedures are well-publicized in the homes.

In addition to evaluating the direct care staff, we polled the supervisors to obtain their opinions as to the improvement of the staff. They were asked to rate the staff's improvement on a scale of 1 to 5, with one 1 being little to no improvement and 5 being substantial improvement. These results are presented in Table 6 and the questions are available in Appendix F.

Table 6: Results from Supervisors' Ratings of Staffs' Improvement in Various Areas

Facility	Wheelchair Terminology	Identifying Problems	Communication
Providence Street	Supervisor A: 3	Supervisor A: 4	Supervisor A: 4
Delawanda Drive	Supervisor A: 1 Supervisor B: 3	Supervisor A: 3 Supervisor B: 3	Supervisor A: 2 Supervisor B: 4
Leicester	No form returned	No form returned	No form returned
Uxbridge	No form given	No form given	No form given

At Delawanda Drive, one supervisor felt that the staff did a better job of bringing problems to her attention. The disparity in the grades given by the two supervisors at Delawanda Drive may reflect differing levels of improvement depending on which shift the supervisor is overseeing, with the third shift having greater improvements due to their greater involvement with wheelchair cleaning and inspections. Leicester did not return a form to us with these data, and we elected not to give such a form to Uxbridge due to the short duration of their participation and the fact that the only participants were supervisors.

At the conclusion of the project, we contacted Ultimate Mobility, the principal vendor used by the Seven Hills facilities, to obtain their impressions of the staff's performance and of our website. We spoke with Ms. Kelly O'Day, a representative of the company who coordinates repairs with the facilities on a regular basis. When asked whether she had been contacted in the previous five weeks for wheelchair repair issues, she responded that neither Seven Hills facility had contacted her at all. She was surprised by the lack of repair requests. She also indicated that

her staff had looked at the website and were impressed by the content. They had no specific suggestions or complaints but did ask to use it in other capacities, as part of their In-Service training program.

Discussion

From the experiences of the staff members during the course of the study, we have arrived at several conclusions and recommendations as to the feasibility of implementing a web-based wheelchair maintenance program for the Department of Mental Retardation's facilities and its contractors. Among the most prominent and critical challenges is access to computers and the Internet. At present, the computers are not generally accessible to the direct care staff. Each home has only one or two computers which are located in the directors' offices or in locked cabinets that impede access. In one facility, the only computers are in the basement, which is not on the same floor as the wheelchairs. This effectively precludes routine computer use. Supervisors are the only staff members with guaranteed access to the computers. We found that the staff did not use the website as frequently as we had originally intended. We believe that this is most likely due to the inconvenience of having to gain access to a computer in order to access the web materials. For example, at one facility, the entire third shift was unable to use the computer for a week due to the supervisor's absence. Consequently, we supplied a printed version of the website for their use. Given the logistical realities of the facilities, it would be simpler and more convenient for the staff to have access to printed versions of all of the documentation. The website could serve as a backup version that could be updated to supply new versions of the print materials to all facilities. The website would be more applicable for use by the supervisors rather than the direct care staff.

Certain aspects of the web documentation lend themselves toward printed copies rather than purely electronic versions. For example, having hard copies of the checklist and glossary that are easily transported and brought near to where wheelchairs are being worked on would be

to the advantage of the staff. It is unreasonable to expect them to find a computer and take the time to browse through the website for every minor wheelchair issue.

The difficulties and inconvenience of accessing the website consequently make it difficult to assess whether the documentation itself, electronic or printed, is effective in communicating with the staff. However, we were able to analyze the text of our glossary and troubleshooting sections using the Fog index. The former rated 8.7 and the latter 4.5. Both of these scores are well within the range of readability for most people. On numerous occasions, we requested feedback as to the ease of use of the website and suggestions for its improvement. Throughout the course of the study, very few such comments were received. This suggests that many of the staff did not have an opportunity to use the website. Since the computers are not generally available to the staff, the website went largely unused. If computers could be set up as dedicated kiosks in common areas where wheelchairs are actively being used, then a web-based solution may be more viable.

Furthermore, reticence toward computer use proved difficult to overcome. The direct care staff had no prior experience with computer use in the DMR workplace setting. Given the short time period over which this study was conducted, this reality likely affected the staff's willingness to adopt a new working philosophy that integrated computers into their daily routines.

Despite the obstacles presented by web access, we were able to obtain useful data from all of the facilities except Uxbridge, where the sample size and length of trial were insufficient. We noted improvements in all five areas that we evaluated; however, each home had different areas of improvement. Results, consequently, were mixed. Overall, the greatest improvements

came in wheelchair terminology, followed by repair protocol and wheelchair data collection, mechanical knowledge, and problem diagnosis. We were disappointed to see that the staff had few improvements in diagnosing problems, but it was gratifying to see the positive trends in wheelchair terminology. Improvements in the diagnosis of problems likely would require a longer period of study so that the staff could gain more experience with the chairs and more practice using the checklist on a routine basis. In fact, Providence Street, which received the test wheelchair more times than any other facility (four times rather than three times), showed the only improvement in diagnosing problems. This may be due to the additional time spent inspecting the chair.

With regard to the documentation itself, it was difficult to evaluate whether it met the needs of the facilities as few people had the opportunity to use it. DMR and its representatives examined the website and deemed its content sufficient to meet the reference needs of the direct care staff. At the final presentation meeting on 23 April 2008, DMR representatives from offices statewide felt that the content was appropriate. Furthermore, the website received the approbation of Ultimate Mobility, one of the vendors which has frequent communication and interaction with the facilities. Despite approval from this level, it was not possible to determine if the content met its goals for appropriate language and ease of access for direct care staff. With regard to the checklist, some staff complained that it took too long to complete. Most staff reported a time for completion between 30 minutes and one hour. It is likely, however, that this time would be reduced with additional familiarity.

If we were to conduct this test again, we would make several adjustments based on our experiences. Firstly, having paired data sets would permit us to analyze the results with more sophisticated tools and obtain a more robust set of conclusions. To this end, a system of

assigning numeric identifiers to each person for individual tracking while still preserving their anonymity would be implemented. Such a procedure would require written informed consent and the approval of the WPI Institutional Review Board (IRB). This would also require greater care to be taken to ensure that all staff members who took the pre-test also took the post-test. This type of study would also likely be better served by being spread over three terms instead of two. This would permit a longer period for testing with a greater probability that problems on the facilities' chairs would occur. There would also be more flexibility in scheduling around vacation time and unforeseen events. A longer testing period could also be used to include more homes in the study. Furthermore, we suggest redesigning the content to be more applicable to printed copies and use the website to provide updated versions of this content and information specific to supervisors. Each home could then have a hard copy of the material that could be brought to where wheelchairs are being worked on. For the third shift staff, we advise defining a set schedule for weekly wheelchair inspections on their own chairs. The number of repair forms that we obtained from each facility was often low and highly variable. Tighter control over who is completing the forms would better assist researchers in generating useful results. Finally, the elimination of the planned one-week pilot test had no real effect on the outcome of the project, since five weeks proved insufficient for the staff to adapt to the web material. Consequently, one week would most likely not provide any useful data. As indicated by the results at Uxbridge, we could not have gathered any useful information in such a short time period.

There are also several factors that may have artificially influenced our results and must be taken into account when evaluating the performance of this study. When the test wheelchair was inspected, it is possible and even likely in some circumstances that staff collaborated in finding problems. While acceptable in practice, this effectively reduced the size of our sample. During

the pre-test and post-test, we attempted to keep cooperation to a minimum; however, it is possible that some staff members exchanged answers. Our own biases may have also influenced the grading of the exams. It would have been more statistically valid to have a disinterested third party complete the grading of all exams. We attempted to adhere to our established rubric as closely as possible. Having unpaired data sets also reduces the effectiveness of our analysis. Differences in the operating philosophies and communication between supervisors and staff may also have affected how the staff used the documentation and how thoroughly they committed themselves to the test program.

For future studies, the focus should be on creating a printed version of the website and retooling the web material so that it is more applicable to supervisors. The printed material would need substantially more organization than the web material, including a detailed table of contents and index. The glossary should be revised to include pictures in line with the definitions. Furthermore, some of the documentation, including the glossary, the labeled photographs, and the checklist, could be presented in poster format. These could be hung in the facilities for the general reference of all of the staff. Further studies could then use this written material to evaluate the documentation directly without the barrier of computer access. A set of guidelines for supervisors to introduce the documentation to new hires could also be useful. Finally, a means of collecting wheelchair information such as brand, model number, serial number, and vendor, upon receipt of the wheelchair would aid in the organization of records and simplify filling out the repair forms. A set of documentation for electric wheelchairs probably would be of limited benefit owing to their complexity and the specialized knowledge required of repair technicians. It may be useful to have a general list of parts specific to powered wheelchairs.

Conclusion

This Interactive Qualifying Project was intended to develop a set of documentation for the maintenance and repair of manual wheelchairs at group homes managed by DMR and its subcontractors. This documentation was designed to be in the form of a website that would be publicly accessible. Once developed, this documentation was tested through a pilot program with the participation of four such homes in the Worcester area.

The maintenance and repair handbook was based on the work of two previous project groups (Trimby et al., 2004 and Young & Holmes, 2001). We modified this previous maintenance manual by simplifying the terminology and limiting the depth of mechanical familiarity needed to complete the most basic of wheelchair repairs. The use of proper wheelchair terminology was of primary importance, as improving communication with vendors would speed the repair process considerably. Emphasis was also given to establishing a uniform procedure to be followed in the event of wheelchair problems.

A pilot program was conducted over a five week period at four DMR group homes. Direct care staff were introduced to the documentation and encouraged to use the manual during daily wheelchair inspections. We evaluated the success of the documentation with both written and practical examinations. The written tests measured improvements in knowledge of wheelchair nomenclature, mechanical knowledge, and repair protocol knowledge. The practical portion of the examination consisted of the staff's inspections of a test wheelchair to diagnose problems and record the pertinent wheelchair data.

Through analysis of the data collected from these tests, we showed that results among the four facilities were mixed. The greatest improvements came in knowledge of wheelchair

terminology, while problem diagnosis showed little change. Computer access proved to be a difficult logistical obstacle to overcome in the facilities we visited. As the direct care staff do not have access to computers on a regular basis, an online solution is not the most viable option for DMR. Furthermore, printed material is more convenient for the staff to use while performing wheelchair maintenance and inspection. Consequently, we recommend that the web materials that we developed be reframed as a printed resource. This could be distributed via the Internet to make updating simple, but the website should be focused on the needs of supervisors and information that could help them in their communications with vendors. Furthermore, this study could benefit from a longer test period, which would permit the direct care staff to gain greater familiarity with the documentation and experience inspecting wheelchairs. Future research should focus on expanding the scope of this study to examine the documentation in a printed form.

This project has demonstrated that the provision of a wheelchair maintenance manual coupled with implementation of staff training and protocols for wheelchair inspection has the potential to improve staff knowledge of wheelchair terminology and basic maintenance procedures. These changes can be expected to reduce wheelchair repair time through improved communication between direct care staff and wheelchair vendors.

References

Berg, Bruce L. (2007). *Qualitative Research Methods for the Social Sciences.* Boston: Pearson.

Boissel, J. P. (2004). Planning of clinical trials. *Journal of Internal Medicine, 255*, 427-438. doi:10.1111/j.1365-2796.2004.01311.x

Coolen, A., Kirby, R., Landry, J., MacPhee, A., Dupuis, D., Smith, C., et al. (2004). Wheelchair skills training program for clinicians: A randomized controlled trial with occupational therapy students. *Archives of Physical Medicine and Rehabilitation 85*, 1160-1167. doi:10.1016/j.apmr.2003.10.019

Cowley, Mike. (2005). Maintenance scorecards: measure what you manage: scorecards offer an easy way to track and evaluate maintenance effectiveness. Here's how to put them to work in any industrial environment. *Industrial Maintenance & Plant Operation 66*(2), 12-18.

De Groote, P. (1995). Maintenance performance analysis: a practical approach. *Journal of Quality in Maintenance Engineering , 1*(2), 4-24. doi:10.1108/13552519510089556

Doyle, James K. (2006). Introduction to survey methodology and design. In Handbook for IQP Advisors and Students (10). Retrieved January 18, 2008, from http://www.wpi.edu/Academics/GPP/Students/ch10.html.

ERIC / AE Staff. (1999). Designing structured interviews for education research. *PracticalAssessment, Research & Evaluation, 5.* Retrieved January 21, 2008, from http://pareonline.net/getvn.asp?v=5&n=12.

Fitzgerald, S.G., Collins, D.M., Cooper, R.A., Tolerico, M., Kelleher, A., Hunt, P., et al. (2005). Issues in maintenance and repair of wheelchairs: A pilot study. *Journal of Rehabilitation Research and Development, 42*, 853-862. doi:10.1682/JRRD.2004.10.0130

Friedman, D.H. *FOG Index Calculator*. Retrieved May 7, 2008, from http://www.panix.com/~dhf/fog.html

Hansen, R., Tresse, S., & Gunnarsson, R.K. (2004). Fewer accidents and better maintenance with active wheelchair check-ups: A randomized controlled clinical trial. *Clinical Rehabilitation, 18*, 631-639. doi:10.1191/0269215504cr777oa

Katzin, Emanuel. (1985). *How to Write a Really Good User's Manual.* New York: Van Nostrant.

Kirby, R. L., Mifflen, N., Thibault, D., Smith, C., Best, K., Thompson, K., et al. (2004). The manual wheelchair-handling skills of caregivers and the effect of training. *Archives of Physical Medicine and Rehabilitation, 85*, 2011-2019. doi:10.1016/j.apmr.2004.02.014

Langsrud, O. (2004). *Fisher's Exact Test*. Retrieved April 4, 2008, from http://www.langsrud.com/fisher.htm

Parida, A. (2007). Study and analysis of maintenance performance indicators (MPIs) for LKAB: A case study. *Journal of Quality in Maintenance Engineering, 13* (4), 324 - 337. doi:10.1108/13552510710829434

(2007). Smart survey design. Retrieved January 23, 2008, from http://s3.amazonaws.com/SurveyMonkeyFiles/SmartSurvey.pdf.

Trimby, A.J., Sarcione, J.A., & Kopec, C.L. (2004). Evaluating a Wheelchair Maintenance Resource. Unpublished Interactive Qualifying Project. Worcester Polytechnic Institute.

Vineyard, M., Amoako-Gyampah, K., & Meredith, J. R. (2000). An evaluation of maintenance policies for flexible manufacturing systems: A case study. *International Journal of Operations & Production Management, 20* (4), 409-426. doi:10.1108/01443570010319156

Weiss, Edmond H. (1991). *How to Write Usable User Documentation*. Phoenix, AZ: Oryx.

White, Heather A. & Kirby, R.L. (2003). Folding and unfolding of manual wheelchairs: An ergonomic evaluation of health-care workers. *Applied Ergonomics, 34*, 571-579. doi:10.1016/S0003-6870(03)00079-6

Young, A.S. & Holmes, E.A. (2001). Development of an educational resource for preventive wheelchair maintenance. Unpublished Interactive Qualifying Project. Worcester Polytechnic Institute.

Appendices

Appendix A: P. E. De Groote's Maintenance Performance Indicators[2]

Maintenance Cost Related Economic Ratios

$$\frac{Direct\ cost\ of\ maintenance}{Added\ value\ of\ production}$$

$$\frac{Cumulative\ costs\ of\ maintenance\ of\ a\ production\ unit\ since\ start-up}{Number\ of\ operating\ hours\ since\ start-up}$$

$$\frac{Total\ maintenance\ manpower\ cost}{Total\ direct\ maintenance\ cost}$$

Spare Parts Related Economic Ratios

$$\frac{Average\ stock\ value}{Replacement\ value\ of\ production\ equipment}$$

$$\frac{Cumulative\ value\ of\ issued\ spares\ over\ a\ 12-month\ period}{Average\ stock\ value\ over\ a\ 12-month\ period}$$

$$\frac{Cumulative\ value\ of\ issues\ over\ 12\ months - Cumulative\ value\ of\ issues\ of\ safety\ parts\ over\ 12\ months}{Average\ stock\ value\ without\ safety\ parts}$$

$$\frac{Total\ store\ issues\ and\ direct\ purchases}{Total\ direct\ maintenance\ cost}$$

Manpower Related Economic Ratios

$$\frac{Cost\ of\ subcontracting\ (manpower)}{Direct\ cost\ of\ maintenance}$$

$$\frac{Cost\ of\ maintenance\ personnel}{Direct\ cost\ of\ maintenance}$$

[2] See De Groote (1995) for a description of the use of these MPIs

Technical Ratios

Indicating Availability:

$$\frac{Planned\ production\ time - Unplanned\ downtime}{Planned\ production\ time}$$

Indicating Speed:

$$\frac{Actual\ amount\ of\ production}{Planned\ amount\ of\ production}$$

Indicating Quality:

$$\frac{Actual\ amount\ of\ production - Non-accepted\ amount}{Actual\ amount}$$

$$\frac{Theoretical\ production\ time - Planned\ downtime}{Theoretical\ production\ time}$$

$$\frac{Theoretical\ production\ time - Hours\ for\ maintenance\ (planned\ and\ unplanned)}{Theoretical\ production\ time}$$

$$\frac{Number\ of\ gross\ operating\ hours}{Number\ of\ gross\ operating\ hours + Downtime\ for\ maintenance\ (planned\ and\ unplanned)}$$

$$\frac{Number\ of\ hours\ of\ downtime\ for\ unplanned\ maintenance}{Number\ of\ gross\ operating\ hours}$$

$$\frac{Number\ of\ production\ stops}{Number\ of\ gross\ operating\ hours}$$

$$\frac{Number\ of\ maintenance\ hours\ (planned\ and\ unplanned)}{Number\ of\ gross\ operating\ hours}$$

$$\frac{Number\ of\ man\ hours\ for\ troubleshooting}{Number\ of\ man\ hours\ for\ planned\ maintenance}$$

$$\frac{Man-hours\ spent\ on\ prepared\ work}{Total\ man-hours\ spent\ by\ maintenance\ personnel}$$

$$\frac{Sum\ total\ of\ time\ allocated\ for\ maintenance}{Sum\ total\ of\ time\ actually\ worked\ on\ these\ jobs}$$

Appendix B: Trip Reports

16 January 2008

- Attending: Nikolas Ledoux, David Willens, Thomas Mercier, Holly Ault, Allen Hoffman
- Location: Second Floor Conference Room, Higgins Laboratories, WPI
- Contacts
    - Tom Mercier: main liaison for WPI at the Hogan Regional Center
    - Jan Rusiecki and Peter Treyer: Central West Regional Office
    - Bruce Klockars: Monson Residential Facility
- Website
    - Layout was good, but content needs updating
    - Some information is outdated and/or too detailed
    - Prefer to have simpler repairs for lay persons and send chairs out to vendor for more involved repairs
    - Staff should be educated in wheelchair terminology to communicate problems more easily
    - Preventive maintenance and awareness of failure modes would be more cost-effective
    - Links
        - Some are outdated and need to be updated
        - Some not applicable
        - Add links to Worcester-area manufacturing and repair facilities
- Facilities
    - Lack of knowledge of wheelchair fundamentals
    - More efficient to incorporate maintenance procedures and checklist into daily cleaning done by the overnight shift
- Current operations
    - Procedure for repairs has multiple complicated steps that delay the return of the wheelchair
        - Prescription must be created for insurance purposes by the staff member
        - Dealer must be contacted who must visit facility and verify problem
        - Dealer visits approximately each week
        - Dealer then makes determination as to repair procedure
        - Turnaround on the order of weeks
        - If staff were better educated, then initial trip from dealer could be eliminated
- Pilot test to begin at the beginning of D-term in 4 Worcester locations plus 2 others without any prior interaction (locations yet to be determined); tours available
- Other facilities to be used as controls
- Decision trees complicated but potentially useful if simple enough

31 January 2008

- Participating: Tom Mercier, Bruce Klockars, Kathy, Lorri, Daniel Asselin, David Willens, Nikolas Ledoux
- Held at the Monson Developmental Center, Palmer, MA
- Current manual is viewed as overly complex, dense, and difficult to understand for the lay person
    - Should have an index and a glossary of terms
    - Must be designed for ease of online viewing: prefer to have entirely computer-based system
        - Pilot test for other online resources
    - Pictures and diagrams for several commonly used chairs
        - Most common model is Invacare 900 series
    - Revision to manual is most important aspect of the project according to DMR
    - Need a list of warnings and alerts that will prevent basic problems, such as using the wrong screw size or tool size (SI vs. English units)
        - Use wheelchair symmetry to advantage
    - Manual must include only those repairs that DMR believes its staff can handle
- Checklist is written in repair technician jargon; must be simplified
    - Would be implemented during evening cleaning
    - Derived from an internal repair document and not designed for educating other people
- Internet access is available in all facilities according to Tom's information
    - Details will be forthcoming as to exactly how many computers are available and how accessible they are to the staff
    - Current staff uses Internet only for email
- Communication
    - Disconnect between the home care staff and the repair personnel
    - Staff may have limited English skills
    - Need to learn basic nomenclature for wheelchairs
    - Should be able to locate model and serial numbers
        - Records for older serial numbers are not kept by manufacturers
        - Repair personnel encounter difficulties with locating information
        - Would be useful to have an internal database to track pertinent wheelchair data
    - Possible improvements also include a bulletin board discussion system and an instant message repair helpline
- Current program
    - No inspections and no routine maintenance is done at the facilities

- Staff waits for catastrophic failure before contacting repair center
- Delay is in getting information from the staff to the repair personnel
- Most repairs complete in less than an hour
- Substitute chairs are available
- Repair requests are accepted via mail or phone
    - Problems are often discovered by one person and then passed on to someone else for report
    - Residents are not typically capable of identifying/reporting problems
- Prefer to see chairs every 4 months for inspection
- All repairs are conducted at the Palmer facility except for electronics
- Records are kept for maintenance and repairs
- Vendor repairs can take 3-4 weeks
- At one facility, estimate more than 100 wheelchairs

4 February 2008

- Facility: 197-199 Providence Street, Worcester, MA
- Present: Daniel Asselin, David Willens, Nikolas Ledoux, Thomas Mercier, Sue Anderson
- We were able to inspect several chairs currently in use
    - Tom explained various parts and common issues with wheelchairs
        - Backpacks hung on head rests cause bending of components
        - Tilt wheelchair cables are often damaged by hanging objects on chairs
        - Brakes often loosen due to use of extenders
        - Many parts are interchangeable among numerous models
- We met several residents and viewed their chairs
    - Most seem well-aware of their wheelchairs and problems with them
    - Several were excited about receiving new wheelchairs
- Facility is well-kept but theft seems to be a problem
    - Director reported several instances of missing equipment
    - Computers are kept locked up; not as accessible as hoped
    - Director assures us that staff will have Internet access when needed
- Current repair impressions
    - Director believes new hires lack common sense in many instances
        - Do not know how to document a problem (i.e. do not remember where broken parts were found on the floor, what has broken)
    - Repairs take several weeks to effect
    - Nearly a complete lack of basic tools at the group homes
    - Language barrier can be problematic in communicating with repair personnel
    - Revised manual must be written in the most basic terms possible, suitable for employees whose native language is not English
    - We witnessed a wheelchair issue firsthand
- Director extended an invitation to us to return when necessary for further questions and information

13 February 2008

- Location: 153 Delawanda Drive, Worcester, MA 01603
- Attending: Daniel Asselin, Nikolas Ledoux, David Willens, Thomas Mercier, Kerry McGowan (facility director), Dianne Hughes (Asst. facility director) Sharon Goldberg (Asst. VP of Community Services), Karine Joseph (director of Leicester, MA home)
- There are 5 manual wheelchairs in use at the facility
    - Tom offered additional suggestions for material to include in the manual
- We were able to inspect each of them and get some impressions from the residents
    - Some residents had new chairs
    - All were satisfied with the performance of the chairs
    - One complaint concerned the cleaning procedures (wheelchair not cleaned properly)
    - The facility has a contract with Ultimate Mobility to provide wheelchair repair and maintenance
        - Ultimate Mobility supplies them with a checklist and maintenance guidelines
        - They also supply cleaning instructions
        - The staff also take advantage of periodic training programs offered by the supplier
- One staff member was competent with wheelchairs and tools
    - A full set of tools was available according to the recommendations of Ultimate Mobility
    - Some staff members seemed overwhelmed by the number of tools required
    - Inspections are done twice daily already during cleaning periods after meals
- All staff were very motivated in general and enthusiastic about the results of the project
    - They offered us an unused wheelchair to keep
    - Meticulous records of all communications and repairs are kept
    - Staff follow up with dealers in the event of problems
    - It is usually possible to eliminate the first inspection visit by the dealer by carefully explaining the problem (Leicester home needs improvement in this regard)
- Internet access in limited at the facility
    - Restricted to office space and specific users (not direct care staff)
    - Web access in limited to the Seven Hills website (but ours can be added)

20 February 2008

- 200 Trapelo Road, Waltham, MA; the Eunice Kennedy Shriver Center
- In attendance: Daniel Asselin, Nikolas Ledoux, David Willens, Thomas Mercier, and John Rochford
- The current website is not accessible and does not meet the state's design standards.
    - JavaScript prevents screenreaders from operating properly.
- Accessible websites must meet the following:
    - No JavaScript
    - No frames
    - No pop-up windows
    - Basic HTML code only
    - Contextual information for links and images
- John recommended several websites with accessibility checking tools and standards.
- Tom answered some of our questions about the content of the glossary.
- Our schedule for implementing the test program was preliminarily approved by Tom; he will be checking with one of the two homes we have visited already to determine which would be prepared to host the first trial program.
    - Centers need sufficient lead time to arrange staffing and schedules
    - Designating a wheelchair repair specialist will require union approval but should not be a major obstacle.
- DMR would prefer far fewer links on the website
    - Three major dealers in Massachusetts
    - Two or three manufacturers only
- There will be another meeting in Palmer at the Monson Developmental Center during the March break so that Bruce can offer suggestions for the documentation before implementation.
- At the end of D-term, DMR would like us to present our project to DMR's assistive technology team.

Appendix C: Interview Questions

The following interview questions were prepared for the meeting on 31 January 2008 at the Monson Developmental Center in Palmer, MA. The questions were designed to gather basic background information and to gauge the current level of expertise and familiarity with wheelchairs and maintenance protocols. We also asked the staff and supervisors similar questions during our initial visits.

Broad Goals:

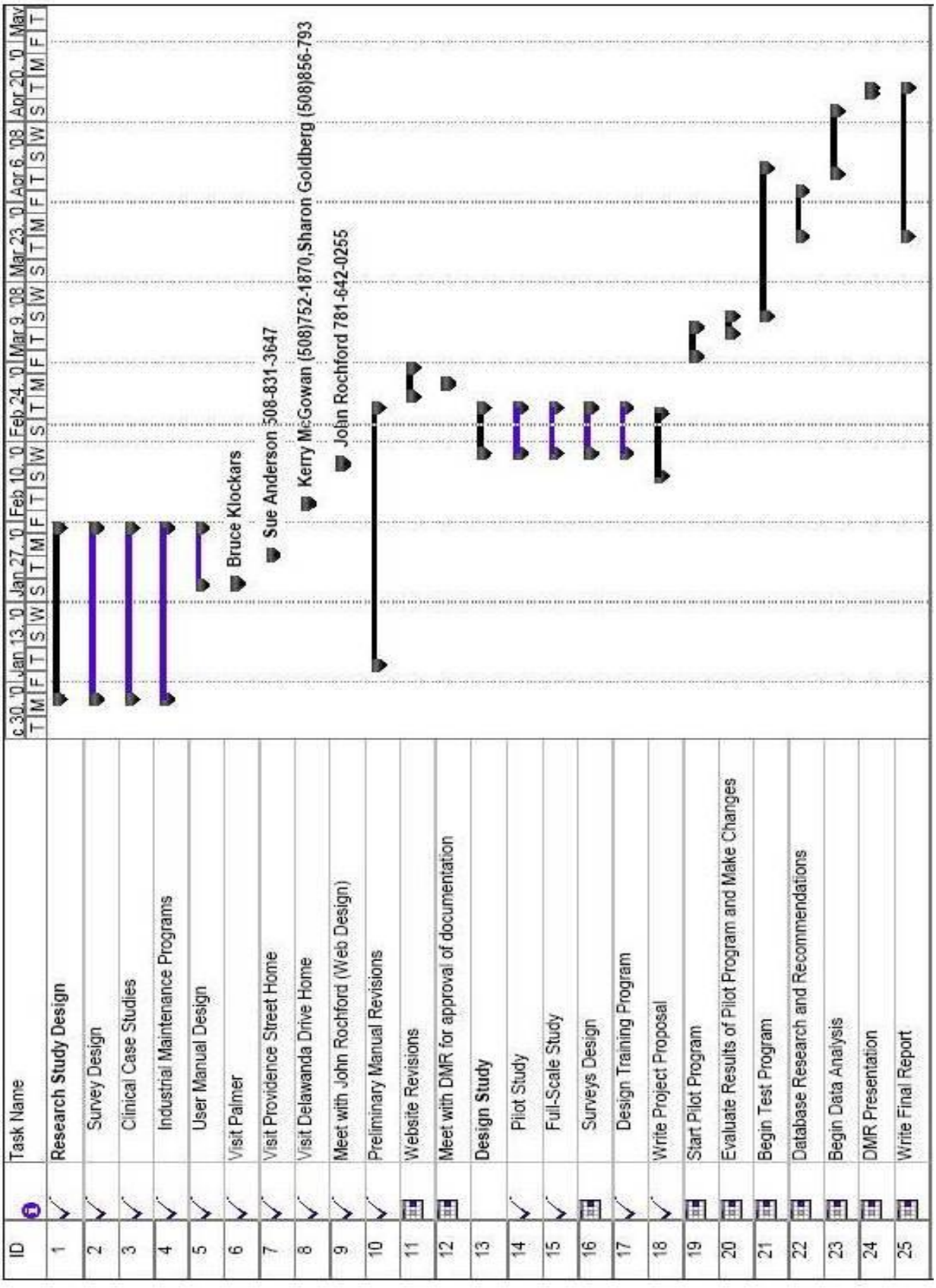
- Evaluate routine
- Most common repairs, most common problems with wheelchairs
- How best to implement a daily inspection
- Online form: what needs to be included
- Can we speak to some residents?
- Which homes in Worcester shall we be visiting?

Questions for repair personnel:

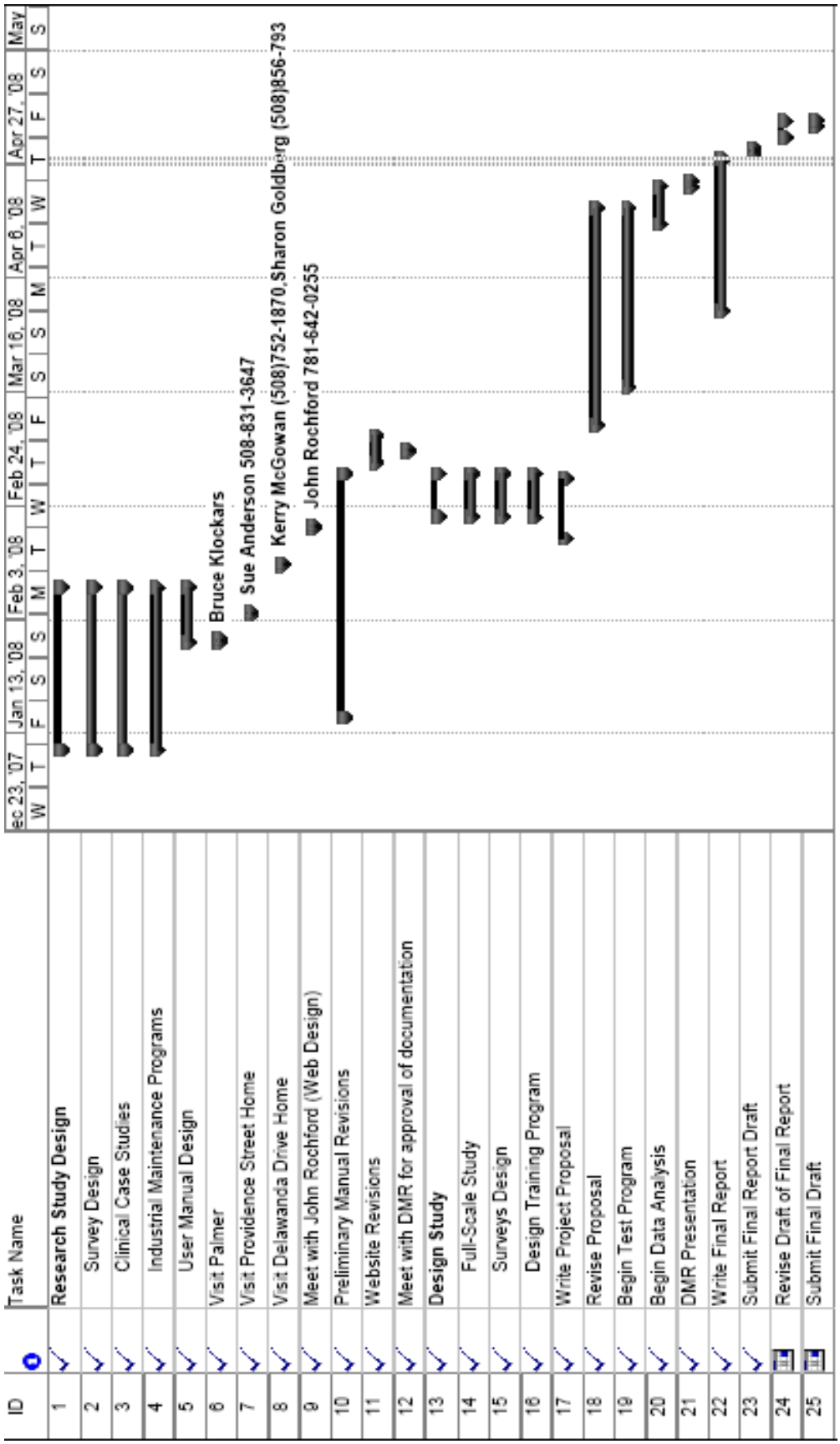
1. How often are chairs inspected?
2. What is involved in an inspection?
3. What routine maintenance is performed? How often?
4. What happens when a chair needs repair?
5. What are the most common unplanned repairs?
6. What types of repairs do you do?
7. What types of repairs are performed by others?
8. Who performs these repairs?
9. Do you keep maintenance and repair records for each wheelchair?
10. Who usually identifies problems?
11. How are problems reported?
12. Do the residents themselves report problems with their wheelchairs?
13. What types of problems do they report?
14. What is the average time from the report of a problem to the return of the wheelchair to service after repair?
15. How much time is spent on unplanned maintenance?
16. How often do you think chairs should be inspected?
17. How many wheelchairs are maintained at this facility?
18. Do you have access to the Internet during the course of your workday?

19. Do you use the Internet to perform your job? If so, how?
20. How do you use the Internet personally, outside of your job?
21. Are you comfortable using an online reference as opposed to a hardcopy repair manual? Which would you prefer?
22. Are there any areas of the current repair and maintenance processes that you feel need improvement?

Appendix D: Gantt Chart (planned as of start of D-Term 2008)



Appendix E: Final Gantt Chart



Supervisors please comment on the following items:

Please rate improvements on a scale from 1 to 5 (1=little to no improvement, 5=substantial improvement) on the following 3 questions.
Comment on any areas you feel necessary.

1. Direct Care staff's use of proper wheelchair vocabulary: _____

_____

2. Direct Care staff's ability to identify wheelchair problems: _____

_____

3. Direct Care staff's ability to communicate wheelchair problems effectively: _____

_____

Appendix G: Raw Data

Facility	Terminology	Mechanical Knowledge	Protocol Knowledge	Problem Diagnosis	Data Collection
Providence	Pre: 63/77 Post: 74/38	16/24 23/9	19/11 20/4	3/15 35/49	4/5 31/5
Delawanda	Pre: 79/131 Post: 95/115	19/41 28/32	13/32 25/20	4/8 18/52	1/5 22/8
Leicester	Pre: 43/97 Post: 49/49	17/23 16/12	9/21 13/8	16/68 6/22	17/25 8/4
Uxbridge	Pre: 14/14 Post: 21/7	6/2 8/0	3/3 5/1	2/4 4/3	2/1 3/0

In the above table, the results of the pre and post tests are organized by facility in each of the five categories that were tested. For example, the results of the pre-test for Providence Street, in the terminology category, were 63 correct answers and 77 incorrect answers. The first number is the number of correct answers recorded in the particular question category. The second number is the number of incorrect answers in the particular category. In the protocol knowledge category, Delawanda Drive had 13 correct answers and 32 incorrect answers on the pre-test. On the post-test, Delawanda Dr. had 25 correct and 20 incorrect answers.