WRITTEN COMMUNICATION PRACTICES AS IMPACTED BY A MAINTENANCE RESOURCE MANAGEMENT TRAINING INTERVENTION

J. C. Taylor
Santa Clara University
Santa Clara, California
and
Robert L. Thomas, III
Alliant International University

ABSTRACT

Written communication was examined in a large airline company that had implemented a Maintenance Resource Management training program. Respondent recollections of training content regarding written communication, along with trends in archival paperwork error data, were examined throughout training periods. Data from written work turnover documents were also collected from one site and analyzed to explore specific written communication practices and to examine training effects on such practices. Implications for future research geared to airline maintenance error reduction are discussed, as well as conclusions regarding program impact on error reduction.

James Taylor holds a Ph.D. in organizational psychology from the University of Michigan. He has been studying the effects of Maintenance Resource Management programs in the airline industry since 1989. He has presented his research at numerous professional conferences such as the SAE Advances in Aviation Safety conferences and the Ohio State University Aviation Psychology Symposia. Dr. Taylor's current research is funded through NASA Award #NCC2-1025 to Santa Clara University as part of a cooperative research program between the Federal Aviation Administration Office of Aviation Medicine (FAA/AAM-240) and NASA Ames Research Center.

Robert Thomas holds a Master of Arts degree in Experimental Cognitive Psychology from California State University, Fresno, and a Master of Arts degree in Organizational Psychology from Alliant International University, where he is a doctoral candidate. His past research interests have included the effects of group collaboration on recollection of material. His collaborative work in this area has been published in the Journal of Experimental Psychology and presented as posters at American Psychological Association conferences. He has assisted in the evaluation and observation of Maintenance Resource Management programs since 1999.

INTRODUCTION

The Role of Written Turnover in Aviation Maintenance

A concept of central importance to aviation safety that is covered in most Maintenance Resource Management (MRM) training programs is the practice of clear and thorough communication. A number of airline accidents caused by human factors can be traced to erosion in either verbal or written exchange of critical information (Taylor & Christensen, 1998). The role communication has been shown to play in human factors error underscores its value as a research construct. More specifically, written work turnover and other documentation represent critical aspects of high-risk organizational systems. Because the complexity of such high-risk systems has been a theorized contributor to accident rates (Perrow, 1999), the clarity and accuracy of written work turnover are critical leverage points for maintenance error reduction. Essential components of accountability, information flow and quality, and safety assurance hinge on the proper and complete use of written communication.

As written communication is so vital to safety in airline maintenance, it is no surprise that efforts have preceded the present research to increase the quality of documentation. Hutchinson (1997) examined work cards in a large repair station and found that over a twelve-month period, 40% of them contained vague, ambiguous or abbreviated phrases that missed intended standards of federal aviation regulation. A feedback system was implemented on the hangar floor whereby work-record error rates were posted daily for mechanics to see. Being shown error rates with such rapid feedback had a profound impact on documentation practices, with the 40% error rate dropping to zero in eight weeks.

Taylor and Christensen (1998) highlight the importance of written communication in airline maintenance, calling it "the bedrock of all communication in maintenance" (p. 94). Of all modes of communication operating in such a system, Taylor and Christensen see the written message at the core. They cite three critical factors in improving written communication in airline maintenance. One factor is employee participation. Involving employees in the improvement process has shown to be a positive force in reducing paperwork errors (Taylor, 1994). A second critical factor is ergonomics and forms design. Research has explored this area to maximize the clarity and usefulness of work documents in airline maintenance (Patel, Drury & Lofgren, 1994). Finally, measurement and feedback on performance is important as Hutchison (1997) has shown. Efforts to measure patterns in written communication and provide feedback to researchers, managers and mechanics about improving this skill help initiate a process geared toward safer airline maintenance departments.

The present study marks an initial attempt to measure some qualities of written communication beyond the mere absence or presence of discrepancies. It is also an effort to examine the effects of a MRM training program containing modules on improving written communication in general and written turnovers in particular. That training took place in two phases. For the large repair hangar described here (hereafter called the *subject site*) Phase I training occurred from January 2000 through April 2000, the period during which all participating employees went through the first day of training. Phase II, the second day of training, began for the subject site in June 2000 and concluded in August of 2000. Other sites in the same company (hereafter collectively called the *subject company*) had started the training, but had not yet completed it. Their interim results are compared with the subject site. Further comparison uses some results from MRM programs in two other companies, whose programs did not include modules on written communication and whose training was completed in one phase.

A Definition of Written Turnover

We are defining *turnover* in organizations employing shift work as the passing of partial or incomplete jobs from one shift to the next. More specifically, written turnover is denoted as the documentation of work performed and passed from at least one shift to another during aircraft overhaul. Written turnover in the airline industry serves two crucial purposes: (a) it leaves a paper trail of accountability for each step in a set of maintenance procedures and (b) it provides the next work shift with information vital to assuming the next stage of a task and ultimately completing the entire job. Important to conclude from this description is that the work card represents a carefully crafted centerpiece to a system of checks, re-checks, accountability and safety nets. Written turnover practices represent the critical human component to this system that ultimately determines the system's ability to reduce maintenance error.

For the subject company, written turnover was emphasized primarily in Phase I of the training, with cursory reminders occurring during Phase II. Specifically in Phase I, the *Three Cs* (clarity, completeness and correctness) were stressed as critical to written communication. Training exercises demonstrating the importance of such written communication included a task that involved following a complete set of directions, the clarity (or unclarity) of which was not apparent to participants until the very last step. A second exercise had participants write a work document entry, striving for enough clarity, completeness and correctness to enable a second, naïve participant to correctly assemble a set of objects in a particular fashion based on what was written. Additionally, considerable time was spent in

discussing and examining company turnover documents and how to fill them out properly.

Research Hypotheses

Based on the emphasis in Phase I training toward written communication and turnover, our expectation was that turnover quality and attitudes toward written communication would be most improved immediately following this period, and that errors in written documents would be diminished.

Hypothesis 1: Following training, the subject company'' respondents' intentions to write more clearly, and subsequent reports of their having written more clearly and improved their turnovers will be higher than other companies not using this training.

Hypothesis 2: Following training, paperwork errors in the subject company will show a decrease coincident with behavior change.

Hypothesis 3: Following training, the actual written turnovers would improve in length (completeness), in legibility (clarity) and in content (correctness), compared with appropriate pre-training baselines.

METHOD

Kirkpatrick (1998) identifies four levels of training evaluation criteria or outcomes, each increasing in relevance to bottom-line organizational goals. The four evaluation levels articulated by Kirkpatrick in order of increasing importance are reactions, learning, behavior and results. Reactions are simply the opinions of training participants about the training. Such data is easily measured and collected, but has a theoretically and practically weak relationship to ultimate organizational goals. The second level of evaluation, learning, carries a bit more weight toward bottom-line training objectives. An evaluator targeting this level of criteria is interested in principles, facts, and attitudes that were gained or changed as a result of training. Behavior is the third level of evaluation and represents more direct connection to work practices. An evaluator at this level is looking for actual behavior change or reports of behavior change related to job performance. The final, deepest and most critical level of evaluation criteria, according to Kirkpatrick, is results. At this level, training effects are related to organizational objectives. If an evaluator can demonstrate that this level of criteria is affected by a training initiative, then that evaluator has data that are able to make meaningful statements about the success of the program.

The data used in the present study was collected with the Kirkpatrick concepts as a model, and with primary attention to the second, third and fourth levels of evaluation criteria (learning, behavior and results). Kirkpatrick warns that evaluation of results is generally difficult to obtain. Former attempts have been made to link MRM training to bottom-line organizational results (e.g., ground damage incidents and lost time injuries) (Taylor, 2000).

The current study is an attempt to measure a behavioral process in aviation that is very closely related to fourth level evaluation criteria. An overriding organizational objective in the subject company, as well as the greater aviation industry, is the minimization of incidents and accidents. We are examining the quality of written turnover as a behavioral criterion shown by accident investigations to have direct consequence for these safety objectives (e.g., NTSB, 1992).

Subjects and Samples

The subjects (employees of the subject site) are aviation maintenance repair mechanics and quality inspectors, plus their immediate supervisors and middle managers who have completed a two phase MRM training program in a maintenance repair site belonging to a large airline. The subject site is unique in that *all* of its employees have completed both phases of this MRM training, which emphasized improving written turnovers. Initial field interviews at the subject site during and after the training period revealed that many participants especially valued its sections on written communication and turnover. Results from this subject site are compared with other heavy maintenance facilities in the same company (subject company) that had begun, but had not yet completed, the same MRM training. Survey results from the subject site and the larger subject company are compared with heavy maintenance operations in two other airlines (*comparison companies A and B*) whose MRM training did not include the topics of written communication or improving written turnovers. Survey respondents in the comparison companies include mechanics, inspectors, and management and support personnel in similar proportions to the subject company.

DATA

Assessment of Written Turnover Quality

The documents from which we assessed the quality of written turnover in the subject site consist of non-routine work cards that are included in the document packages resulting from aircraft heavy maintenance overhaul called maintenance checks. These maintenance checks are a set of preplanned maintenance inspections and procedures, which are conducted

at required intervals for aircraft of a particular model. The non-routine work results from defects or damage found during the preplanned inspections. The overhaul process studied here is called *C-check* in the industry and is a fairly extensive overhaul process. Because the set of maintenance procedures for a C-check is so large, the subject company has divided theirs into six parts that can each be performed usually in three to four days of nine to twelve eight-hour shifts.

For each non-routine job card they work on, these maintenance employees are required to sign the entries for which they accept responsibility using their own stamp issued with their employee ID number. The employee who stamps the repaired by section on the front of the card accepts responsibility for his or her section, as well as any entries on the card that have not been stamped. The checked by section of a work card is generally stamped by an inspector, meaning this individual is accepting responsibility that the completed job has been conducted properly, and that any required inspection items have been properly inspected.

Sampling Written Turnover Data

The subject site's data sample represents turnover data entries recorded by the mechanics, inspectors, supervisors and managers in this one heavy maintenance station. All turnover entries were recorded by employees that had completed both phases of the MRM training during the preceding year. Turnover data were collected and coded from completed work documents during visits to the company archives. A purposeful sample of document packages was drawn. We could not review all non-routine work cards for the subject site with the time and manpower available. We therefore sampled the documentation of approximately 10% of all C-checks performed at the subject site for a two-year period. Because no grounded or theoretical reasons could be conceived to choose one phase of the C-check over another, our sample was selected without regard for the phase of C-check other than gaining an adequate proportion of the total checks conducted in 1999 and 2000. The population consisted of 179 document packages in 1999 and 169 in 2000, a total of 348. From this, a sample of 16 packages from each of 1999 and 2000 were included in the sample, a total of 32. Phase I training began in January of 2000 and concluded in March of 2000. Phase II began in June of 2000 and concluded in August of 2000.

Figure 1 shows the distribution of the 1,386 separate turnover entries obtained from the 32-package sample. March, September, and December were selected as appropriate periods in each year to draw samples based on their proximity to 2000 training onset and conclusion. The sample chosen allows examination of changes in written turnover performance at critical points coincident with onset and termination of training. It also allows for
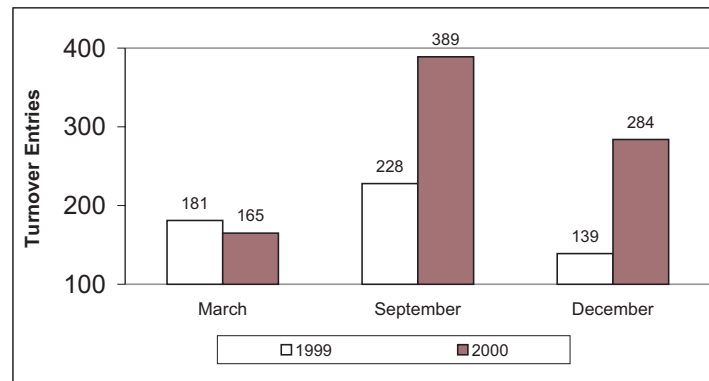
Figure 1. Total Number of Turnover Entries for Each Sampled Month in 1999 and 2000

comparisons to baseline from the same months in 1999, during which training had not yet been implemented.

Coding the Turnover Data

Turnover written in response to the initial inspection and defect description were assessed and coded by two raters. Turnover length (completeness) was recorded by counting the number of words included in the turnover, including reference numbers and abbreviations. Legibility (clarity) was recorded by assigning a rating from 1 (completely illegible) to 4 (completely legible) for each turnover entry. Content (correctness) was recorded by counting the number of times an entry included correct or incorrect information. By industry standards, information on what was done, or information on where the employee stopped or how he or she left the situation is considered correct and information on what to do next is considered incorrect. Raters were compared on turnover length, content and legibility for each time block separately using independent samples t-tests. Number of words (length) and content were stable across raters, with no significant differences between raters. However, comparison of raters on legibility yielded significant differences at almost all time blocks, reflecting the increased subjective judgment inherent in this measure.

Measuring Paperwork Discrepancies

The subject company's airline maintenance department, in which the new training on written communication had been implemented, has measured and reported total paperwork discrepancies for each station by month between 1995 and 2001. The subject company's monthly reports were made available to the researchers for use in identifying improvement

trends coinciding with the training. In order to compare the subject site with others in the subject company, the raw data contained in these reports were corrected for station size through the use of personnel headcount. Trends for these corrected data were examined for a period prior to the onset of the training and for the available months thereafter. Viewing these trends we expected to find the most impact of the MRM training on the subject site in which all employees had completed both phases; and to a lesser degree in the other maintenance stations in the subject company where not all employees had yet been trained.

Survey Measurement

Employee intentions to improve their written communication following their training, and their reports of actually doing so, were collected using post-training surveys. Survey data were collected from the subject company and from two comparison companies using the Maintenance Resource Management–Technical Operations Questionnaire (MRM/TOQ), a well-tested and validated survey instrument (Taylor, 2000). Training participants completed surveys immediately after their training. In the subject company's sites where training occurred in two phases, questionnaire data were collected after each phase. The MRM/TOQ data used to explore the effect of the training on written turnover come from responses to previously validated open-ended items that are subsequently coded into fixed categories (Taylor, 1998; 2000). Initial responses come from the immediate post-training questionnaire, in which participants were asked what was memorable about the training they had just received, and how they intended to use the training. Further responses were collected from participants several months after their training when these respondents received another MRM/TOQ in which they were asked to describe what changes they had actually made as a result of their training. Since the coding scheme included categories for both "writing more clearly," and "improving my turnovers," we expected to find such responses in greater proportion in the subject site, next most frequent in the remainder of the subject company, and the least in maintenance operations at the comparison companies where the MRM training curriculum did not include written communication as a topic.

RESULTS

Comparisons of Written Turnover Before and After MRM Training

Written Turnover Completeness

Figure 2 shows the written turnover length (or completeness) for the subject site for 1999 (the year before MRM training) and 2000 (the year in

which training occurred). As shown in Figure 2, the distribution of mean number of words in turnover arrayed across sampled months in each year are roughly parallel for this measure and higher for 2000.
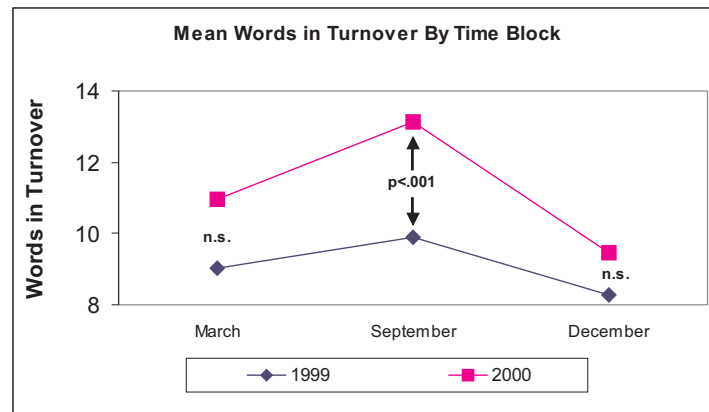

Figure 2. Turnover Length: Subject Site Comparison for Six Time Periods, 1999 and 2000

A one-way analysis of variance (ANOVA) was conducted for turnover length with time period as the factor, and it was significant ($F = 8.892$; $df = (7, 1,808)$; $p < .001$). Tukey HSD post hoc analysis revealed the following. The increase in turnover length between December 1999 and the two periods March and September 2000 are statistically significant ($p < .001$), implying stepwise improvement resulting from Phase I and Phase II training. However there is a significant decrease in turnover length from September to December 2000 ($p < .001$), which suggests that the training effect is short lived. The post hoc analysis shows also the increase in September 2000 (the month following the completion of all training) over the same period in 1999 is significant at $p < .001$. Differences in turnover length remain non-significant when compared for the months of March and December in 1999 and 2000.

Written Turnover Clarity

Figure 3 shows that average legibility (clarity) scores are reasonably high. They range between a low of 3.1 and a high of 3.6 on this 4.0-point scale. The one-way ANOVA of turnover legibility (with time period as the independent variable) is also significant ($F = 13.603$, $df = (7, 1,814)$, $p < .001$). The Tukey HSD post hoc analyses reveal somewhat similar results to those seen for turnover length. As shown in Figure 3 a sizable increase in legibility was found from December 1999 to March and
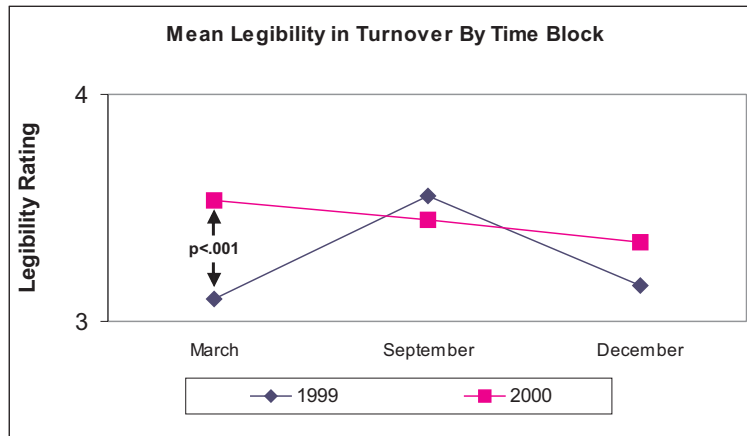
Figure 3. Turnover Legibility: Subject Site Comparison of Six Time Periods, 1999 and 2000.

September 2000 (suggesting an effect of Phase I training), which are significant at the $p < .001$ and $p < .01$ levels of confidence, respectively. The highest level of legibility occurs in March 2000, immediately after Phase I training and is significantly greater than its counterpart a year earlier. No significant changes occurred across time periods in 2000, and no other significant differences emerged for legibility.

Correctness of Turnover: Descriptive versus Prescriptive Narrative

Among the hypotheses tested in this research is the improvement in correctness as well as the completeness and clarity of written turnover documents. As previously mentioned, policy at the subject company and elsewhere in the industry discourages maintenance employees from making statements in the turnover about what the next course of action should be for the employee receiving the turnover. This is because such statements can limit the decision making of the turnover recipient, and additionally the suggested comment may be against authorized procedures. Each entry was dichotomously coded as having either included or not included what was done, how the situation or job was left, and what needed to be done next. From these data, we compared *descriptive* turnover only (stating what was done or how the job was left), and *prescriptive* turnover (adding statements about what the next mechanic should do), on turnover length and legibility.

Legibility (clarity) was not different between descriptive and prescriptive turnovers ($t = -1.95$, df = 2091, n.s.). However, for total number of words (completeness) the prescriptive turnover entries had significantly more words than the descriptive turnover entries. Levene's test was

significant for the t-test used for analysis (F = 32.70, p < .001), and the group sizes were unequal, necessitating a non-parametric analysis. The Mann-Whitney U test showed significant difference in mean ranks at z = –6.154, p < .001. The greater number of words in the prescriptive turnover is no surprise, as additional writing should be required to include direction about what should be done next. This finding reinforces a point made in the subject company's MRM training that longer turnover is not necessarily better turnover.

Unfortunately this advice did not have a measurable effect on performance. Figure 4 shows the oscillating percentages of prescriptive turnover entries across time blocks. An overall Chi Square test (X^2) of the 6 time blocks by inclusion of prescriptive turnover was significant ($X^2 = 37.77$, df = 5, p < .001). Post hoc Chi Square tests were conducted for adjacent time blocks, and significant differences were seen for several of them. A significant decrease was found from September 1999 to December 1999 ($X^2 = 8.65$, df = 1, p < .01), a significant increase was shown from March 2000 to September 2000 ($X^2 = 22.04$, df = 1, p < .001) and a decrease was revealed for the period September 2000 to December 2000 ($X^2 = 14.20$, df = 1, p < .001). Thus no clear effect of MRM training on eliminating prescriptive turnovers can be discerned from the current analysis.
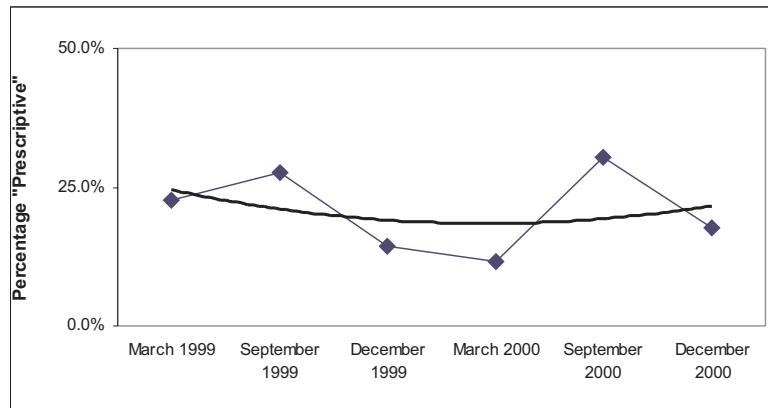

Figure 4. Turnover Content: Subject Site's Percentage of "Prescriptive" Responses for Six Time Periods, 1999 and 2000

Testing other effects on turnover correctness

Pearson's Chi-Square statistic was conducted for each of these variables in cross-tabulation with the three main job titles of mechanic, inspector and manager. Overall 2 x 3 cross-tabulations yielded significant Chi-Square statistics ($X^2 = 21.95$, df = 2, p < .001), indicating a relationship between

turnover content and job title. In 2 x 2 Chi-Square tests, mechanics were shown to be more likely than inspectors ($X^2 = 32.807$, df = 1, p < .001) and managers ($X^2 = 7.082$, df = 1, p < .01) to write a prescriptive response. Managers and inspectors did not differ from one another.

Paperwork Errors in the Subject Company

Figure 5 shows the total number of paperwork or document errors per month from January 1995 to January 2001 for the subject site and the average errors per month for all remaining base maintenance stations in the subject company. A slight positive trend is shown in number of errors across time (the trend line for the subject site is solid and the trend line for the average of the remaining stations in the subject company is dashed), with a sharp increase occurring in 2000 and 2001. Both trend lines in Figure 5 show a positive slope after 1998. This seems perplexing considering the ongoing training program in progress designed, in large part, to reduce these types of errors. However, a hiring freeze ended in the subject company at the beginning of 1998, and a number of young and less experienced mechanics began work for the subject company at the beginning of 1999.
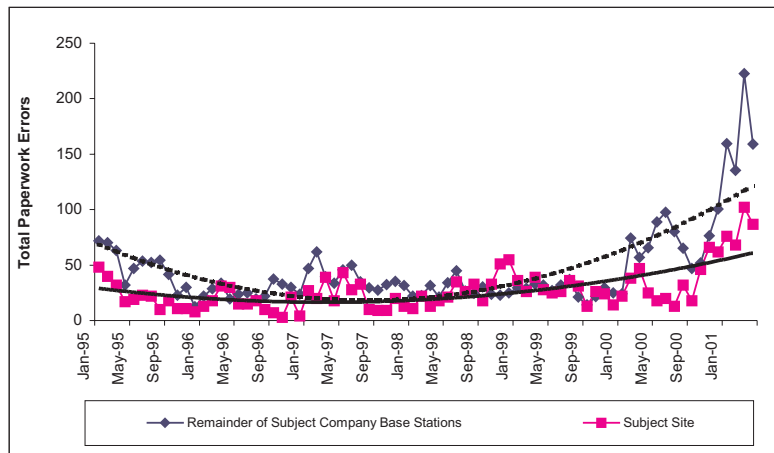

Figure 5. Paperwork Errors from January 1995 through April 2001

Head count data is shown in Figure 6. This shows a slight increase in the number of employees from 1998 to 2001 in the subject site and a stronger growth in new employees in the remainder of the company. Head count data was not available prior to 1998.

We could easily expect that a population suddenly infused with new employees would yield an error trend with an increasing slope. Any
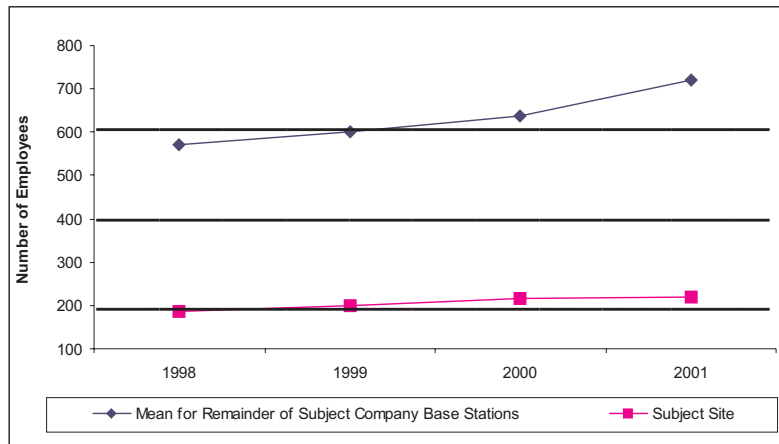
Figure 6. Head Count Data from 1998 through 2001

significant effects of MRM training are likely counterbalanced by the propensity of a new hire to commit error. To assess the possible effects of new employees hired, we adjusted errors by head count and compared the trend line slopes before and after January 1999. Figure 7 shows the year 1998 and the different trends in paperwork errors between the subject site and the remaining heavy maintenance stations in the subject company. The subject site is less affected by new hires in 1998 and shows an error rate increasing more sharply than the head count rate over time, which shows an
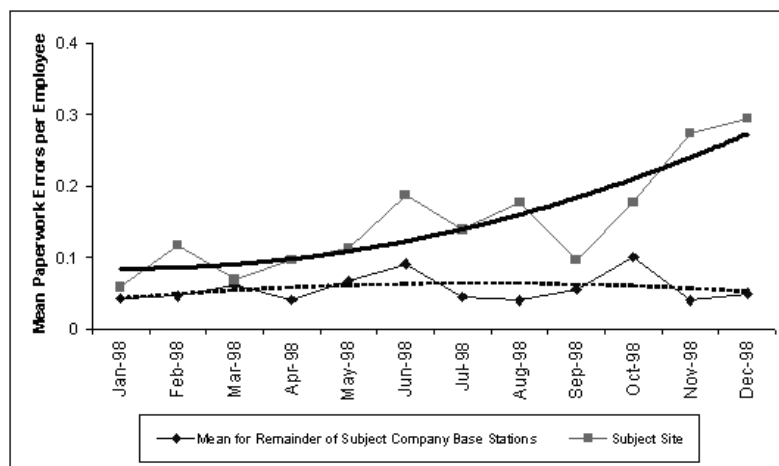

Figure 7. Paperwork Errors Adjusted for Head Count for 1998

overall increase in errors per employee during this time preceding MRM training.

For 1999 through 2001, corrected for head count, Figure 8 shows an increasing trend for both the subject site and remaining stations. This similar shift in trend for both groups lends support to the idea that new and relatively inexperienced mechanics can be largely responsible for the diminished paperwork skills and the increase in paperwork error rates in 1999-2000.
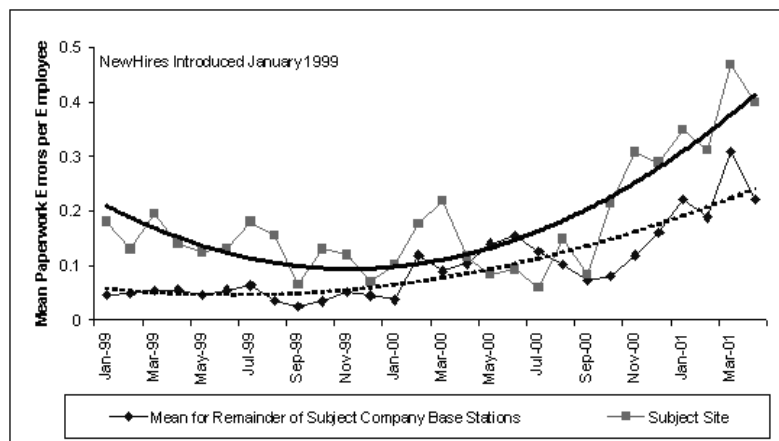

**Figure 8. Paperwork Errors Adjusted for Head Count for 1999, 2000 and 2001
(During Training and after New Employee Hiring)**

Field Interviews and Survey Data

Recollections and Intentions

In field interviews conducted in June 2000, shortly after Phase I training was completed, a sample of 46 maintenance employees from the subject site were asked what they remembered best about the training. "Turnover" tied for the highest response with "case studies and videos" at a 15% response rate. This apparent enthusiasm and remembrance for written turnover was encouraging, since written turnover was a primary component of Phase I training. Interviews conducted with Aviation Maintenance Technician (AMT) and foreman at the subject site in December 2000 showed that AMTs' attempts to improve written turnover had begun, but then ceased. Interview respondents generally agreed to a lack of management support or encouragement for the effort.

Following both Phase I and Phase II, the MRM/TOQ included the questions "What are good aspects of the training" and "How will you use

this training on the job." Among the general themes that are coded for each of these, three bore some relationship to the topic of written turnover. Those themes were "improve turnovers," and "write more clearly," as well as "communication" (this last theme code was used if the respondent wrote only the word "communication" and nothing else). Data from the subject site were compared with the results from remaining heavy maintenance stations in the same company; and both of those are compared with companies A and B that are engaged in similar heavy maintenance operations, but whose MRM training did not cover written communication.

Table 1 shows the degree to which respondents felt the three selected communication topics were memorable (or good) in the training they received.

The results in Table 1 reveal a difference among the six survey samples in their mention of memorable topics that is statistically significant (Chi Square = 41.62, df = 10, p < .001). These results show a substantial regard for the treatment of improving turnovers in the subject site and in the remainder of the subject company immediately following their Phase I training. Improving turnovers was not mentioned at all in the two comparison companies following their MRM training and this is to be expected insofar as their training programs did not emphasize that topic. Likewise, and for the same reason, no mention of the turnover topic was made following the Phase II training in the subject site and the remainder of the subject company. A smaller proportion in the subject sites mentioned clearer writing as a memorable aspect of their Phase I training and this

Table 1. Communication and Turnover Responses for "What were the good aspects of the training?"

What were the good aspects of the training?	"Improving turnovers"	"Writing more clearly"	"Communication"
Following Phase I, Subject Site (n = 245)	7.4%	1.6%	4.2%
Following Phase II, Subject Site (n = 263)	0	0.5%	2.1%
Phase I, Remainder of Subject Company (n = 837)	7.3%	3.4%	7.3%
Phase II, Remainder of Subject Company (n = 236)	0	0.4%	1.2%
Comparison Company A (n = 1,844)	0	0.3%	4.1%
Comparison Company B (n = 153)	0	0.6%	3.8%

X^2 = 41.62, df = 10, p < .001

appears as a very small percentage following Phase II training as well as for the two comparison companies. There appears to be little difference in the general "communication" topic among the six samples except that it seems to diminish in the subject site and remainder of the subject company after Phase II training as specific references to communication are reduced in that training.

Table 2 shows respondents' expectations—as a result of their training—to improve their turnovers, to write more clearly, or to just communicate.

Table 2. Communication and Turnover Responses for "How will you use this training on the job?"

How will you use this training on the job?	"Improving turnovers"	"Writing more clearly"	"Communication"
Following Phase I, Subject Site (n = 245)	6.6%	8.1%	4.1%
Following Phase II Subject Site (n = 263)	1.1%	0.6%	3.0%
Phase I, Remainder of Subject Company (n = 837)	15.6%	8.7%	6.1%
Phase II, Remainder of Subject Company (n = 236)	0.1%	0.8%	3.5%
Comparison Company A (n = 1,844)	0	0.1%	7.2%
Comparison Company B (n = 153)	1.3%	0	7.8%

X^2 = 46.76, df = 10, p < .001

Results shown in Table 2 show that participants in the subject site and in the remaining heavy maintenance stations in the subject company more frequently expressed intentions to improve turnover and write more clearly than in the other two companies. The Chi Square test for difference among the six survey samples over the three response categories is statistically significant (Chi Square = 46.76, df = 10, p < .001). These respondents also most frequently expressed intentions to improve turnovers and write more clearly after Phase I than after Phase II. This reduction of intentions following Phase II training is not a surprising finding considering these topics were not emphasized in Phase II content. The two comparison companies show minimal intentions to practice either improved turnovers or clearer writing. Intentions to improve general communication show little difference among the six samples.

Reports of Actual Behavior

Table 3 displays data collected from the subject company's MRM/TOQ following Phase II, and shows the degree to which respondents say they *did* improve their turnovers, they *did* write more clearly, or they *did* communicate better in general as a result of their training. These results are compared, in Table 3, with data collected from respondents in the two comparison companies in a follow-up MRM/TOQ survey administered two months after their training.

Table 3. Communication and Turnover Responses for "What changes have you made on the job?"

What changes have you made on the job?	*Phase II, Subject Site (n=180)*	*Phase II, Remainder Subject of Company (n=259)*	*Comparison Company A (n=585)*	*Comparison Company B (n=150)*
Wrote more clearly	0.6%	2.3%	0	0
Better turnovers	1.1%	1.9%	0	1.3%
Communication	2.7%	1.9%	1.6%	6.0%

$X^2 = 10.66$, df=6, n.s.

These reports of behavioral change several months after the initial training are suggestive, but cannot be said to statistically support the prediction of respondents' actual change in written turnovers resulting from the training. Although Table 3 data do show a slight trend in the subject company respondents' reports of writing more clearly and improving their turnovers, the Chi Square test does not show a significant difference among the several samples.

DISCUSSION

MRM Training Effects on Turnover Practices

The most direct evidence we have presented here, the analyses of written turnover length and legibility, does yield findings showing benefit of MRM training. For our subject site, which received the maximum effect of the training; turnover completeness (length) increased over 1999 baseline levels in March 2000, after Phase I, and again in September 2000 following Phase II. The second direct, but partial support for our hypotheses lies in the clarity (legibility) results. Legibility increased over baseline after Phase I, but returned to 1999 levels after Phase II. Possibly, legibility is a habit quickly and readily improved, but also more likely to degenerate than writing more complete descriptions.

This failure to fully support our hypothesis might be explained by participant reaction to the second training module, in which the written communications skills were not sufficiently reinforced. In the second training phase, participants get a reminder of Phase I content, and may hear the implicit message that management is committed to the values and ideas advocated in the training. Field observation following Phase I and again after Phase II revealed little management support for improving written turnover in the subject site. Our results, as illustrated in Figures 2 and 3, do show improvement in written turnover from before the training in December 1999 to after the first phase in March 2000 and again for at least one of the measures from March to September 2000. Making a change such as this to improve written turnover, requires support and encouragement from others. It is evident that encouragement was not strong or continuous in the subject site.

The analysis of job titles and turnover content showed mechanics to be the most thorough in their entries, being more likely than managers or inspectors to include all three types of content recorded. These findings are consistent with job roles. Because mechanics are performing a bulk of the actual work, occupational demands may motivate them to write longer and more comprehensive turnover. Consistent with this explanation are the positive sentiment and the stronger intent to improve turnover shown after Phase I than after Phase II revealed in the survey data (see tables 1 and 2).

Participants may have made an initial effort to write more legibly after the first training because it was not too demanding and difficult. Probably because little commitment at the subject site was dedicated to this change, and little reinforcement was received by mechanics, the efforts waned in the absence of reminders or internal incentives. Anecdotal reports from field visits suggest that local management did little to reinforce the content of the Phase I training and that this had dampening effects on mechanics' motivation to apply the training further.

Paperwork errors data provided additional means by which to assess MRM training effects, but they were not conclusive. The employment of a substantial number of new maintenance personnel into the subject company at the beginning of 1999 was shown to confound the data and thus make difficult the detection of any training impact on paperwork error rates. Under these circumstances special technical training in the proper use of forms would be of benefit for the new hires as well as for the more experienced mechanics who were providing them on-the-job guidance and advice. Without such technical training the effect of this diminished basic skill may outweigh any error-reducing effects the MRM training may have provided. That less-experienced workforce is likely responsible for some if not much of the increase in errors following 1998. Similar data were not available from the comparison companies because they had not collected similar or comparable paperwork errors.

Myriad explanations are possible for the somewhat inconsistent results regarding turnover entries, general paperwork errors, and participant expectations following the training. Ultimately, we are faced with little knowledge about the way these specific variables work in organizational research. To our knowledge, there have been no previous studies of written turnover or paperwork errors in airlines or any other industries to date with the exception of the studies and cases referred to in the introduction.

Generalization of Results

Specific Communication Training Changes Attitudes and Behavior

We have found that specific training in improving written communication included in the curriculum of the first part of a two-part human factors training program produces measurable and favorable results. The training program we examined was completed for 263 employees in one maintenance site. In two other of the company's maintenance sites over 800 AMTs and managers completed the first part of the training. Of these latter groups little more than one-quarter had completed the second part of the training at the time of our study. On the basis of the high sampling ratio these two samples represent, and their consistent results following the first part of the training the change effect can be generalized. Phase I training did lead to improvement in measures from Kirkpatrick's Level 2 (learning) and Level 3 (behavior) categories. Resultant changes in written turnover quality (the learned behavior, measured only in the subject site), were short lived and were not sustained long enough to have an effect on subsequent overall paperwork quality or on aircraft safety (Level 4, results).

Two-part Training Does Not Sustain Learned Behavior and Motivation If It Is Not Designed to Do So

We found that changes in perceptions and in intentions followed Phase I, where communication was emphasized, but diminished following Phase II where it was not emphasized. These results are consistent for the subject site and the rest of the subject company–especially when contrasted with the two comparison companies. Our ability to generalize this finding is quite good because those AMTs and managers who attended Phase II training were all of the employees (n = 263) for the subject site, and were a sizable number (n = 236) and proportion (28%) of base maintenance employees for the remainder of the company. The latter proportion can be considered a random sample of the 800 plus AMTs and managers who attended Phase I training.

We reported that interviews from the subject site revealed only a small amount of local management encouragement and support for improved communication during and after the training. The data on turnover quality, also collected at the subject site, provided evidence that the quality of the

written turnovers improved and then diminished in the subject site following Phase I and Phase II, respectively. We did not collect similar data for the rest of the subject company and cannot, therefore, generalize that a similar oscillation in turnover quality would occur everywhere two-part training of this type is used. Lack of management support provides explanation for the oscillation in turnover quality just noted, but corroborating interviews were not conducted in the rest of the subject company so generalization to the rest of the company cannot be made. Local conditions and results in the subject site cannot be generalized to explain causal effects for the positive change in attitude and intention recorded in the subject company, following Phase I, and the diminution of those changes following Phase II. However, the localized dampening effect of poor management support for improving communication in the subject site could help explain its lower intentions and subsequent reported behavior changes in comparison with the total subject company.

The performance data we collected (average paperwork errors per maintenance employee) do not show a subsequent or long term effect of the training. If anything, the effect of adding inexperienced AMTs is seen to increase errors. Lack of local management support for improving written communication in the subject site, revealed in interviews with AMTs and foremen, is also consistent with the accelerating rate of total paperwork errors in that location from the beginning of the year 2000. That accelerating rate of paperwork errors seems more consistent with the lack of local management support for improving written communication than with the simple addition of new AMTs.

CONCLUSIONS

MRM Training Works–Communication Was Improved

In this paper we have reported that a specific training curriculum, with focus on better writing and communication skills, and on documenting turnover, can make a positive difference in aviation maintenance. Results in a single site were shown to generalize to the larger company. Such training increased trainees understanding of written communication, improved trainee attitudes toward communication, and changed their behaviors in that direction as well. Our results also show that a non-specific MRM curriculum will have little impact on improving targeted communication behaviors.

Improved Communication Was Not Sustained

It is clear from these results that specific training is effective in changing behavior, but the impact on the organizational bottom line—on error reduction and aircraft safety—is illusive. Our results also show that there are several obstacles to improving the bottom line of turnover documents.

The first obstacle is that when employees are ignorant or uninformed of paperwork details and processes, they will make paperwork errors. A successful maintenance operation needs to provide a thorough grounding for its new AMT employees in understanding the company's forms and documents. The company's technical training department should provide this basic and thorough grounding in use of forms and documents soon after an employee is hired.

The second obstacle is a lack of management support and encouragement for improved communication processes and techniques. When such techniques are part of a larger human factors (MRM) program to reduce human error there is the added risk of undermining AMT confidence in the overall MRM effort. Local management may hold the perception that encouraging AMTs to use good written communication practices will act against meeting production demands. When those fears become known to employees (as they surely will eventually) the latter will quickly become cynical of such training in particular and of MRM programs in general. Management must provide support and encouragement for AMTs to take the time to provide written descriptive narrative in a complete and legible form. If managers are ambiguous about (or inconsistent in) providing AMTs the time to complete turnover forms clearly and legibly, this inconsistency will be seen as confusion (or, worse yet, duplicity) to those subordinates.

The third obstacle to address in successfully reducing human error is the individualistic occupational culture of the North American aircraft mechanic (Taylor, 1999). The strong, silent type has many virtues, but in a complex world of modern aviation technology maintenance technicians need to communicate more than has been formerly expected by the industry. This normal tendency of AMTs to communicate less rather than more is only enhanced when their managers are reluctant or hesitant to support what MRM programs encourage.

Management Must Take A Clear and Active Role in Change

The conclusion that local management must be consistent and forceful in its support of company MRM training programs is reinforced by previously reported results regarding obstacles to successful organizational change in the airline industry (Taylor, 1998; Taylor & Christensen, 1998; Patankar & Taylor, 2000). In every instance studied over the past dozen years the one key variable in successful MRM programs is unwavering management support at all levels. It is time for aviation maintenance management to take a clear and active role in promoting and supporting the human factors and error reduction programs they impose on their employees.

REFERENCES

Hutchinson, III C.R. (1997). Aviation speedometers, metrics on the hangar floor. *Ground Effects*, Jan-Feb, 1-5.

Kirkpatrick, D. (1998). *Evaluating training programs: The four levels*. Berrett-Koehler Publishers, Inc.: San Francisco.

NTSB. (1992). Aircraft accident report: Britt Airways, Inc., dba Continental Express Flight 2574, in-flight structural breakup EMB-120RT, N33701, Eagle Lake, TX, September 11, 1991. NTSB/AAR-92/04, Washington, D.C.: National Transportation Safety Board.

Patankar, M., & Taylor, J. (2000). *Human resources integration master plan: A response to revolving door management*. SAE Paper 2000-01-2128. SAE Advances in Aviation Safety Conference & Exposition, Daytona Beach, FL.

Patel, S., Drury, C.G., & Lofgren, J. (1994). Design of workcards for aircraft inspection. *Applied Ergonomics, 25* (5), 283-293.

Perrow, C. (1999). *Normal accidents, revised edition*. Princeton University Press: Princeton, NJ.

Taylor, J.C. (1994). Using focus groups to reduce errors in aviation maintenance(Original title: Maintenance Resource Management [MRM] in Commercial Aviation: Reducing Errors in Aircraft Maintenance Documentation, Technical Report—10/31/94). Los Angeles: Institute of Safety & Systems Management, University of Southern California (available at www.hfskyway.com/document.htm).

Taylor, J.C. (1998). *Evaluating the effects of maintenance resource management (MRM) interventions in airline safety* (Annual Report FAA Grant #96-G-003), 1998. Santa Clara University (available at www.hfskyway.com/document.htm).

Taylor, J. C. (1999). *Some effects of national culture in aviation maintenance*. SAE Technical Paper 1999-01-2980. SAE Airframe/Engine Maintenance and Repair Conference, Vancouver, B.C.

Taylor, J.C. (2000). Reliability and validity of the 'Maintenance Resource Management, technical operations questionnaire' (MRM/TOQ). *International Journal of Industrial Ergonomics, 26* (2), pp. 217-230.

Taylor, J.C., & Christensen, T.D. (1998). *Airline Maintenance Resource Management: Improving Communication*. Society of Automotive Engineers: Warrendale, PA.