12.0 EVALUATING THE EFFECTIVENESS OF MAINTENANCE RESOURCE MANAGEMENT (MRM)[1]

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WHAT IS MRM AND HF TRAINING?

A Definition of MRM.

Taken together, two recent innovations in maintenance define MRM. These innovations are 1) labor-management cooperation for improving safety and 2) the development of positive and assertive communication practices. MRM, by this definition, is not addressing individual human factors of the Aviation Maintenance Technician (AMT) or his/her manager, but it is involved in the larger system of human factors concerns involving AMTs and managers (and others) working together to promote safety.

MRM is an original and creative response to an event of great significance. That response is about communication and its results in aircraft maintenance -- an occupation in an industry for which communication was a largely neglected topic. The event occurred in 1988 -- a 19 year old B737, on a scheduled flight in Hawaii, experienced major hull disintegration which was attributed to problems in the airline's maintenance system management (NTSB, 1989). There was sudden awareness of two problems -- the crisis of an aging fleet, and an industry-wide crisis of communication between management and the worker in conducting safe and cost-effective maintenance operations. As MRM has evolved, and continues to evolve in response to these problems, many airlines are discovering that solving them will require changes in management, organization, and organizational culture -- changes requiring collaboration among people, changes beyond people one at a time.

Two social science studies of airline maintenance operation in the US began shortly after the 1988 accident. They were funded and subsequently published by the FAA (Drury, 1991; Taylor, 1991). Other, similar studies in airline maintenance had been conducted in Britain (Lock & Strutt, 1981) and in the Netherlands (Alders, et al., 1989). The effect of poor communication practices had been accurately noted in the U.S. during the 1980's as well (Strauch & Sandler, 1984). The conclusions from all of these studies showed that maintenance management and group effects, such as those noted by the US National Transportation Safety Board (NTSB), could be generalized in part as a problem of poor communication practices and skills throughout the industry.

There was evidence, from some of the airlines studied, that good communication practices were in use, but that these were the exception (Taylor, 1991). Other positive results had been reported outside the US about changes in management style and structure at British Caledonian airlines (anonymous, 1987), SAS-Scandinavian Airlines, and British Airways (Carlzon, 1987; Lima, 1995).

BACKGROUND OF MRM PRACTICE IN THE U.S.

MRM Measures

Four steps to measuring training effectiveness

A relatively low number of companies report the use of evaluation methods which assess and measure behavior changes on the job and/or subsequent change in organizational performance. Rarely do organizations conduct longitudinal, multiple-measure evaluation processes to examine the effects of training programs. The most prevalent method for evaluating training consists simply of evaluating the trainees' reactions to the training and their level of learning. However, to objectively demonstrate the beneficial effects of training programs, a systematic approach should be taken (Kirkpatrick, 1979, 1983; Alliger & Janak, 1990). Kirkpatrick proposed a four level training evaluation model as follows: 1) the trainee's reaction to the training program, 2) the assessment of how well the trainee has learned the course material, 3) the assessment of the trainee's behavior at the jobsite, following this training; and 4) the objective measures of organizational performance (1979). Less than a decade ago a mere 10% of organizations studied reported using all four criteria levels of Kirkpatrick's model (Alliger & Janak, 1990).

Considering these statistics, the MRM evaluation process introduced by the University of Southern California in 1991 (Taylor & Robertson, 1995), and now continued at Santa Clara University, is at the vanguard. Measurement at each of the four levels is implemented to assess the relative effectiveness of MRM programs (Robertson & Taylor, 1996).

The Maintenance Resource Management/Technical Operations Questionnaire

We use several kinds of measures in assessing success of the various approaches to MRM. A cornerstone measure is the "MRM Technical Operations Questionnaire" (MRM/TOQ), a proven instrument containing a core set of attitude and opinion items which assess respondent attitudes and perceptions relevant to MRM practice (Taylor, in press).

The MRM/TOQ is derived from a 1990 version of the Cockpit Management Attitudes Questionnaire (CMAQ) -- a well-known training, evaluation and research tool (*cf.*, Helmreich, Foushee, Benson, & Russini, 1986). The CMAQ questionnaire contained a number of items measuring attitudes that are either conceptually or empirically related to communication and teamwork training provided to flight crews. Taggart (1990) revised the CMAQ for use in an aviation maintenance department, and reported positive initial results following CRM training conducted for maintenance managers in late 1989. Fourteen CMAQ items were eventually adapted for use in the MRM/TOQ and they included some of Taggart's modifications as well. The four MRM practices measured by those 14 attitude items are: sharing command responsibility, teamwork and cooperation, stress management, and assertive communication.

In addition to the 14 items comprising the four attitude scales just described, an additional eleven opinion items are included in the MRM/TOQ. Six of the eleven deal with communicating and setting goals within and between work units. This goal sharing scale has been previously developed and tested in prior aviation maintenance studies (Choi, 1995; Taylor, in press). The five remaining items measure various aspects of a maintenance department's practices in safety awareness. These safety awareness items are drawn from later versions of the University of Texas CMAQ survey instrument.

A Longitudinal Model For Measuring Success

The MRM/TOQ is applied at various points in an MRM change effort. It is used to determine a baseline measure before any program is put into place and is thereby useful in program planning and design. The MRM/TOQ is also used to survey participants before and after an MRM training course. As part of the longitudinal design the questionnaire is used to survey participants' attitudes and opinions in the months following MRM interventions.

For example, the longitudinal application of the MRM/TOQ helps measure and assess how effectively participants' apply and transfer the learning and knowledge from MRM training to the job. In addition to attitude assessment, behavioral assessments at the job site occur several months following the training. We measure these behaviors with self-reports in follow-up questionnaires two, six and twelve months after training as well through confirmatory field investigation and observation.

Organizational performance measures, provided by participating companies, are tracked longitudinally, before and after the implementation is completed. These measures are correlated with the post-training attitudes and behaviors. This demonstrates the ultimate effects of the MRM program. To accurately assess those measures is a challenge that we address directly. Initially it was argued by Kirkpatrick (1979) and further supported by Steven & Hellweg (1990) that evaluation efforts employing performance data are not far beyond what they were in the 1960s. Furthermore, these researchers claim there still is a necessity for innovative and rigorous social science techniques for evaluating training through performance.

A combination of data analysis methods drawn from Survey Research, Ethnographic Research, and Econometric Research is applied in the following longitudinal model shown in Figure 12.1.

MRM Intervention (Changes in policy, practice, structure, training) undertaken by airlines and repair companies.	Attitudes improve toward vigilance assertiveness, collaboration, and stress management.	Behaviors expected to change due to the MRM changes (e.g., teamwork, open discussion, safe practices).	Opinions increase regarding goal-setting & sharing, and safety climate.	Safety and productivity improvements are related to attitude and behavior changes.

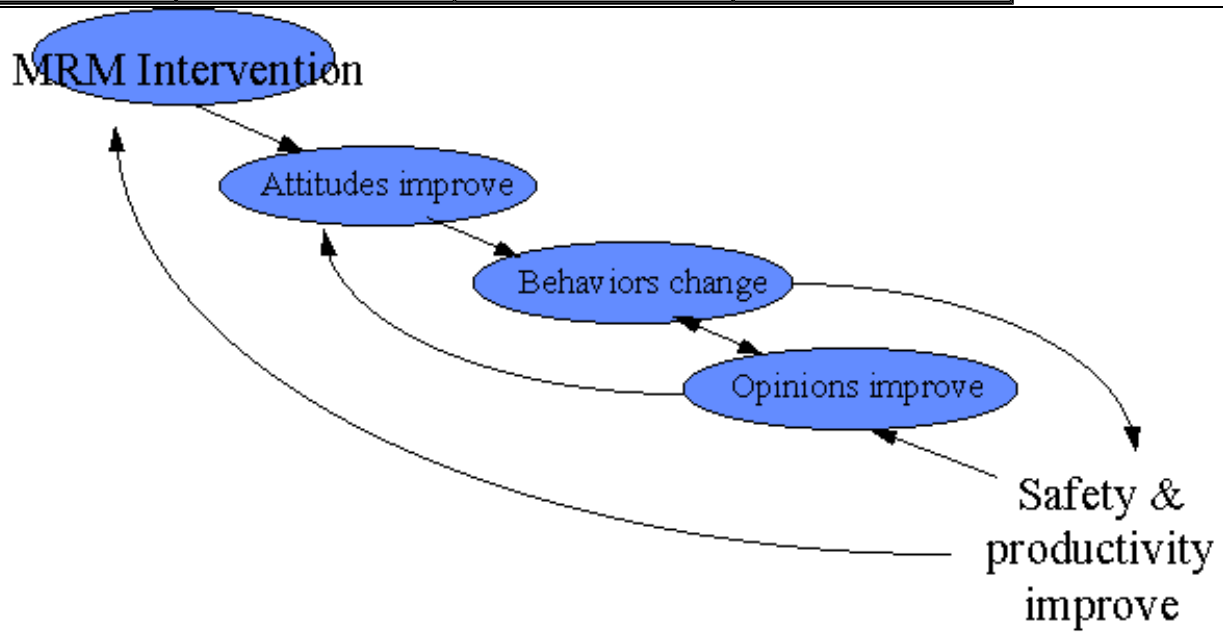


Figure 12.1: A Longtitudinal Model for MRM Evaluation

The USC/SCU Data Base

Since 1991 we have been evaluating MRM-type interventions in U.S.-based aircarriers and repair stations. Those interventions include major programs in four large airlines and smaller interventions in four other airlines and repair stations. In several sites, data collected have covered the spectrum from base-line measures of attitudes and performance to follow-up attitudes and behavior surveys and performance data collected many months, even years, after the onset of the MRM programs. In other locations more limited attitude measurement and few to no performance measures were available. In all, our data base now contains the MRM/TOQ responses from over 7,000 individual aviation technical-operations employees, from all levels and functions (and more than two-thirds of those respondents have completed multiple versions of the survey), as well as some 260 measurement-months for nearly 150 separate stations and repair locations (over 11,000 data points of performance measures).

This data base provides a rich source of information on the effects of MRM programs. The most important findings to date include Level 1 information about the degree of enthusiasm such programs elicit, Level 2 information about the effect of MRM programs on attitudes changed over time, and Level 4 information about the effects of the programs (and of the attitudes changed thereby) on safety and productivity.

HOW EFFECTIVE IS MRM AND HF TRAINING?

Enthusiasm for the potential of MRM training is high immediately afterward. From the beginning of its use in maintenance, MRM-type training has been enthusiastically embraced by its participants – especially immediately following the training. Figure 12.2 shows that effect for five separate maintenance samples measured between 1991 and 1998. At least 60% of these maintenance participants in all five sites feel strongly that the MRM training they just completed will be useful. To obtain a perspective on how strong this maintenance response is Figure 12.2 also includes a typical flight operations sample following their CRM training (Helmreich, 1989). Although flight crews see their CRM training as very useful, the comparable maintenance response is stronger by far.

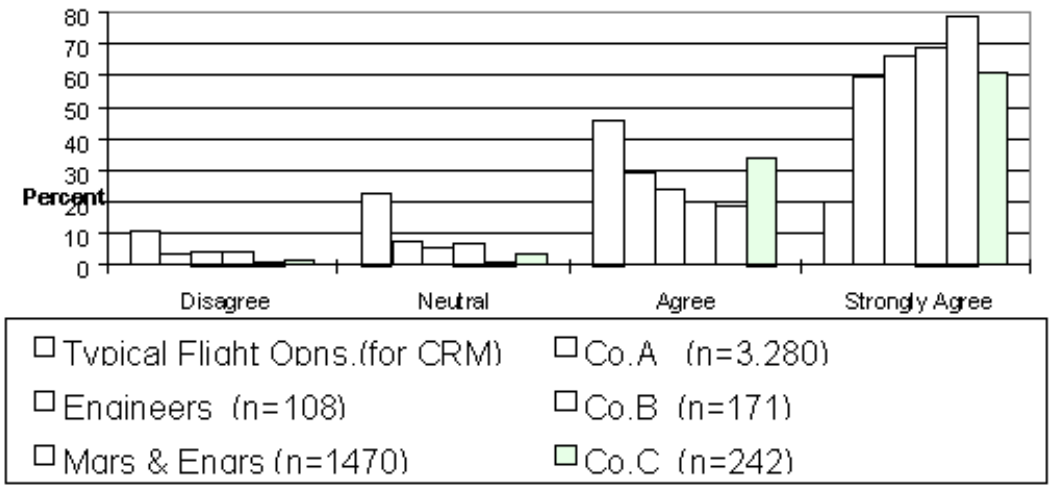


Figure 12.2: Immediate Post-training Reactions: "This training will improve safety and teamwork"

These results in enthusiasm are generally consistent with other reported CRM and MRM training research projects (e.g., Helmreich, 1989; Taggart, 1990; Taylor, 1998). Differences in particular results across companies are more often found in the resulting values and opinions actually shaped by the training. Such differences are likely to be the result of phenomena including, but not limited to differences among the design of the MRM programs and among the organizational cultures (Marske & Taylor, 1997) of the companies themselves.

Attitudes reflecting MRM values increase 15-25% (and more) immediately after training. Across all companies we have studied since 1991, MRM-type training has produced a change in participant values consistent with the focus and direction of that training (Taylor & Robertson, 1995; Taylor, 1998). Each company has designed and delivered its training program consistent with its purpose for that training, whether implicit or explicit. Both the increased endorsement of values following training and the different profiles produced by the different programs are evident in Figure 12.3. For example companies "A" and "B" show a least a 15% improvement in agreement with the value of participative decision making, while the added company, "D," shows the greatest increase in that value. Company "B" on the other hand shows its greatest improvement in values of teamwork and it displays the only improvement in valuing assertiveness immediately after the MRM training. The relative results among these three companies are not coincidental and their patterns match the emphases of their programs.

MRM and Improvements in Safety: What is the Evidence?

MRM training leads to lower occupational injury and aircraft ground damage – with high dispatch reliability. In 1995 we presented evidence that a multi-year MRM-type training effort for maintenance managers and staff professionals had clear and positive connections with subsequent trends in safety without sacrificing flight line productivity (Taylor & Robertson, 1995). That report also established the association between improvement in MRM related attitudes (especially “assertiveness”) and improvements in safety performance.

The connection between MRM-related attitude changes and safety performance was later confirmed for an AMT population -- and in that case the relationship between assertiveness and performance was linked more directly and closely in time (Taylor, Robertson & Choi, 1997).

Studying another MRM intervention with an even larger AMT sample, that direct and timely effect of increases in MRM values (especially the importance of recognizing and managing stress) on subsequent safety performance was further confirmed (Taylor, 1998).

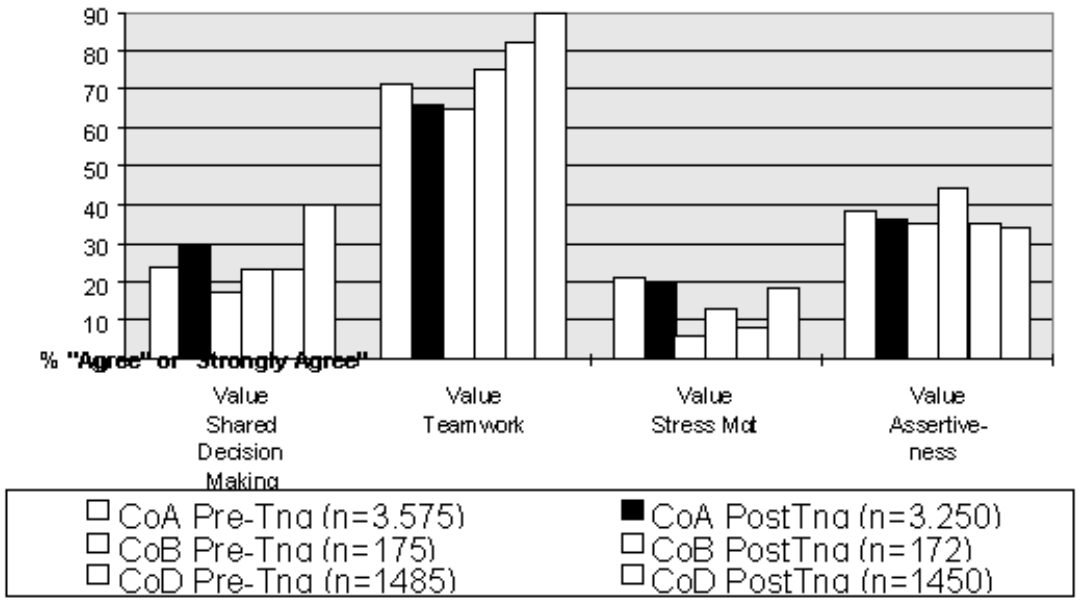


Figure 12.3: MRM Training Effect on Agreement with Values

WHAT ARE THE CHALLENGES FOR MRM?

In recent years airline maintenance departments, large and small, have found encouragement and assistance in undertaking their own MRM programs. Major trends include an emphasis on specially created MRM training for AMTs as well as sometimes including familiarization programs for maintenance managers designed to emphasize the importance of safety and communication.

These trends are well intentioned -- and as described above, highly successful in the short run -- but obstacles and pitfalls remain for the unwary. Particular problems include the over-emphasis on training AMTs and allowing a resulting under-emphasis on simultaneously training maintenance managers to achieve the same communication skills and embrace the same safety culture as their wage-grade workforce. That problem is exacerbated by MRM training which is implemented as a stand-alone program and not part of larger, on-going programs to change maintenance culture toward greater teamwork and safety consciousness. Often such stand-alone training is given a fixed and limited period of time -- half a day, one day, or even two days -- which does not address specific skills training to help participants learn to “walk the talk” as well as “talk the talk.” In other words the current trend for stand alone MRM training for AMTs risks losing true management support, as well as losing the opportunity for AMTs and managers to practice the most important skills of MRM -- cooperation and open communication. Recent experience seems to illustrate that effect.

Despite the many positive results above, continued enthusiasm for MRM programs seem problematic to maintain. In one site recently studied a marked decline in reported usefulness of MRM training and the increased frequency of negative comments about how the training is applied were noted two months and six months following training. AMTs had high initial hopes for the training's impact -- but they fall off dramatically (Taylor, 1998).

Evidence for diminished motivation to change. Figure 12.4 shows mean scores for six attitude and opinion scales measured over time. Comparing these AMTs' attitudes immediately after their training with their pre-training attitudes showed significant improvement on three scales.

Figure 12.4 shows that values espoused in the MRM training about participation, teamwork, cooperation -- as well as the values of managing stress -- all rose significantly after training. Furthermore, these changed values were not a flash in the pan, but they persist over time.

Additionally, participants' assessments of goal sharing at work increased following the training, but then fell back later. Because AMT participants came to the training from different work units and sometimes different shifts they could (and did) recognize their common ground and their "goal sharing" scores confirm this. However, in the following months, that positive opinion diminishes and the six-month score is significantly lower than the immediate post-training survey. Goal sharing has not yet become a robust feature of everyday working life. It has not yet replaced the old culture practice of management goal-tending.

Assessment of maintenance department "safety climate" remained unchanged. This opinion scale measures respondent's assessment of the availability and effectiveness of local safety-related practices and policies. Figure 12.4 shows a fairly high assess of the safety climate overall -- but it also shows little change in that assessment over time. It is not surprising that ongoing policies and practices are not seen to change in the pre- and post-training surveys -- even when safety awareness is a central focus of this training. It is disappointing, however that the safety climate is not seen to improve in the months after the training. These results plainly say that MRM training, in itself, is not enough to effect fundamental departmental practices. In the eyes of the AMTs the safety climate did not improve.

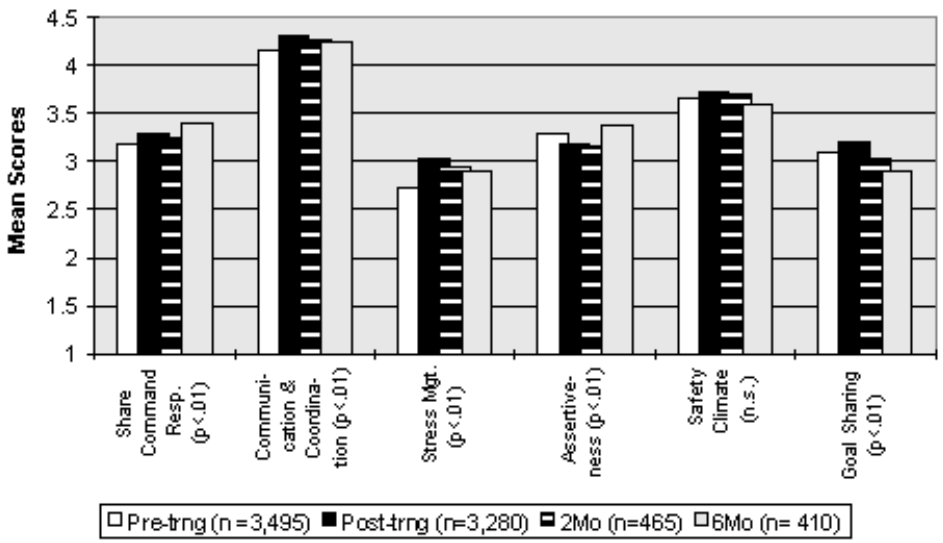


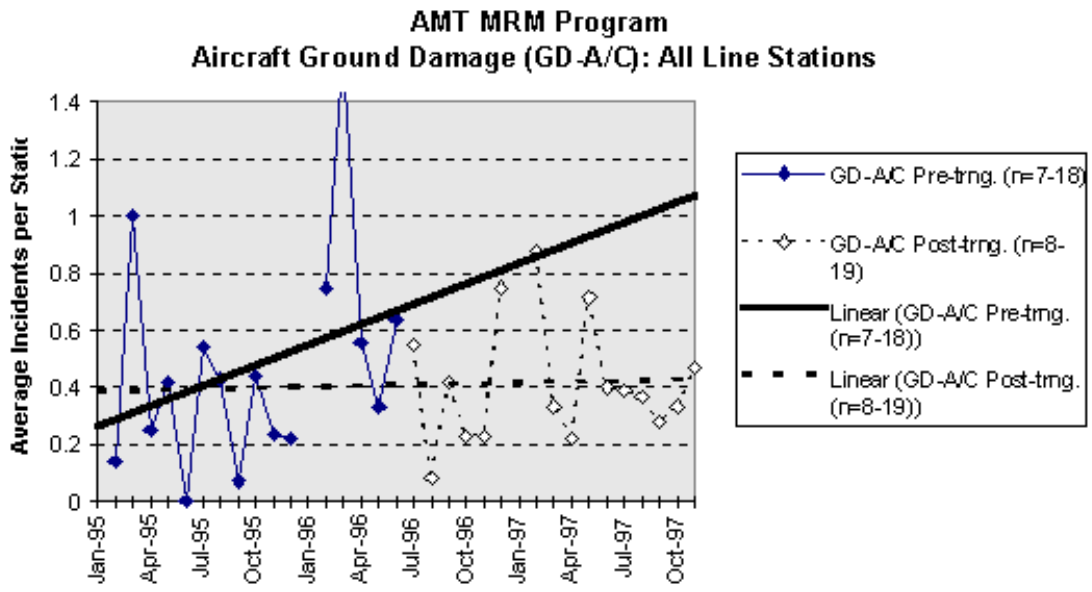
Figure 12.4: AMTs' Views About MRM Topics Over Time

Figure12.4 shows that some important values earned higher marks, and stayed that way. The value of assertiveness dips first then increases in the months following training. That spike of improvement after six months reveals an energy to act. That energy might be seen as arising out of frustration over the difference between the heightened desirability of assertiveness and the existing system's tendency to dampen its actual practice.

Performance Changes Related to the MRM Training. In the 18 months following the onset of MRM training the safety performance for aircraft ground damage and lost-time injuries improved (Figure 12.5).

Positive attitudes toward stress management 2 months after training showed the strongest correlations with low rates of injury and aircraft damage (Taylor, 1998). Stress management is a topic the MRM training program emphasizes and respondents' attitudes show that the training acheived expected improvement. Stress management is an activity that maintenance personnel can do by themselves and which does not require the involvement of others (although cooperation may benefit all parties in this regard). The training helps AMTs and their Leads improve their individual approach to handling stress. As it does so that improvement is related to improved safety. But this continued emphasis on working alone may be placing AMTs in the position of not knowing whether or how much the MRM program is working, or whether other people actually value the lessons of the training as they did. This uncertainty may lead to frustration.

Reported changes from the MRM training are typical in our experience. One question included in the immediate post-training survey and in the 2-month and 6-month follow-up surveys asked respondents to list the personal changes they intended to make following the training. A further question in the 2-month and 6-month surveys asked respondents to list what changes they actually did make as a result of the MRM training.



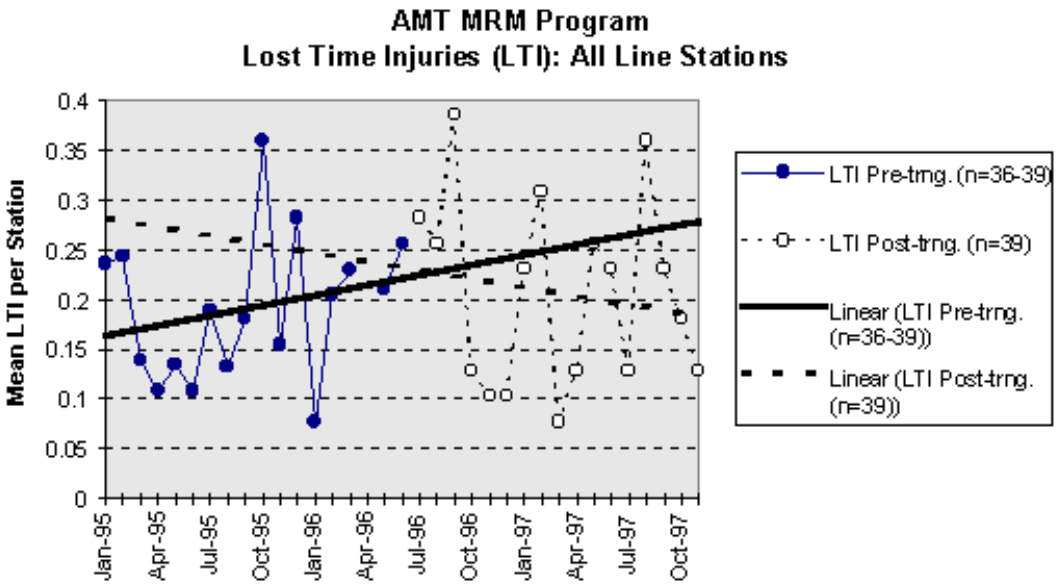


Figure 12.5: Safety Performance Improves following MRM Training

Intentions to change. Figure 12.6 presents that company's employees' intentions to change. Specifically Figure 12.6 a summarized selection of respondents' answers to the question: "How will you use the training on the job?" Results in Figure 12.6 represent the most important and frequently stated answers. Although many other specific answers were given they accounted for smaller proportions of the total [4] and are not included here. For this reason the total percentage for any of the three surveys does not equal 100 percent. But for the immediate post training questionnaire, however, Figure 12.6 shows that three answers account for almost half of the respondents. “More Interaction” (or intending to work more closely and cooperatively with others), “Fight Complacency” (or intending to work more carefully), and being “More aware of themselves and others” totaled 45 percent of the written answers received in the survey at the end of the training. For the 2-month and 6-month follow-up surveys, the total proportion drops to a little over one-third (35% and 34% respectively).

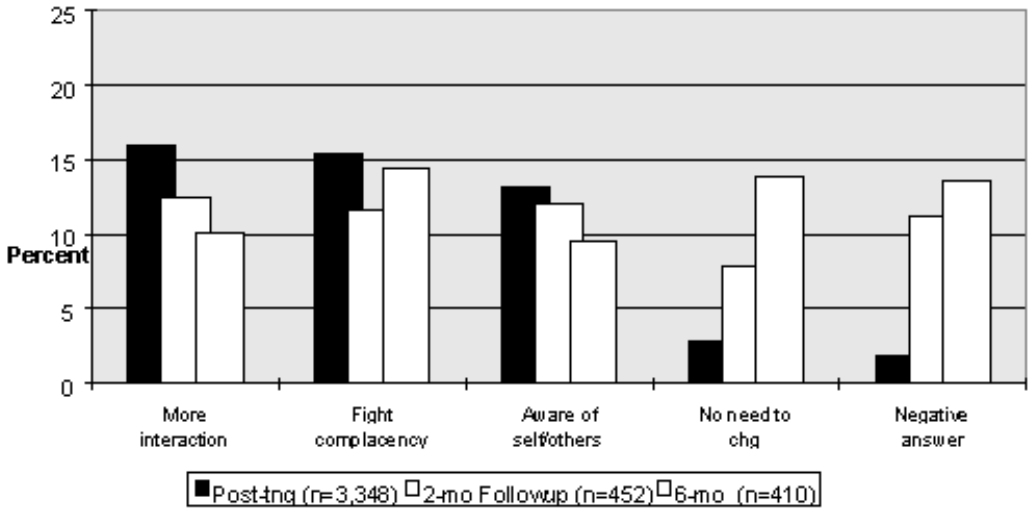


Figure 12.6: How will you use training on the job?

Intentions to change, changed. More important than the drop in those positive intentions is the increase in more critical issues shown in Figure 12.6. The percentage of respondents saying simply that they didn't intend to change, or who made a negative comment about the program or its effects on their future behavior, increased dramatically over time. Those two critical responses together account for less than five percent of the immediate post- training responses, but they increase to totals of 19 percent and 27 percent in the 2-month and 6-month surveys. This is a four- to five-fold increase in negative outlook with the passage of time. Like New Year's resolutions, good intentions definitely faded. Looking behind the summaries at what respondents actually said, many of the negative comments given revealed that respondents had tried to change but they were ignored, or not supported, or they had actually been punished when they tried to speak up and become more active. The culprit is the old culture, exerting its powers of self-preservation, as all cultures do when pressured to change. Cultural change does not come without resistance, ever -- not even when everybody seemingly agrees to the change.

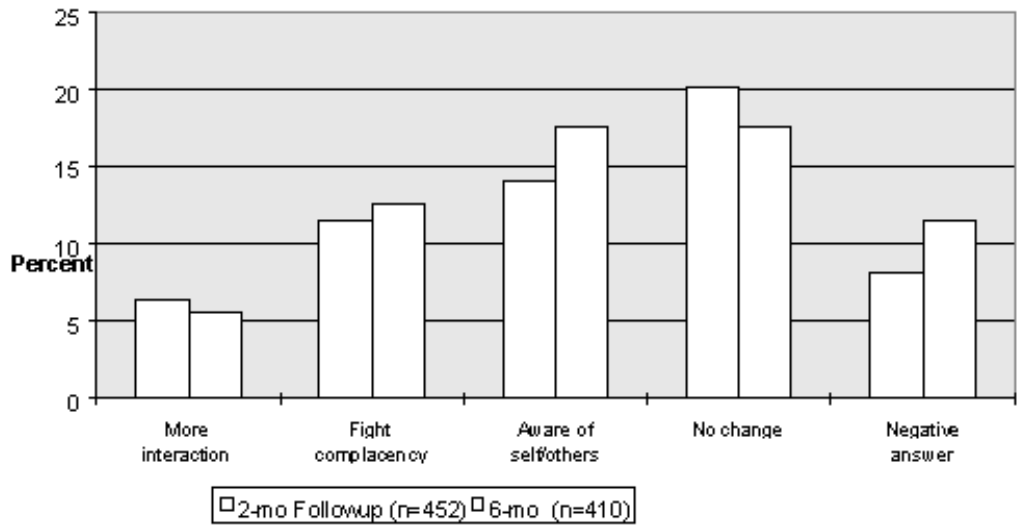


Figure 12.7: How have you used the training?

Reports of changed behaviors. Not surprisingly, Figure 12.7 shows that in the months following training results didn't always match intentions. Although one-sixth of the respondents said that their post-training intentions were to increase interaction and communication with others (Figure 6), Figure 12.7 shows that less than half that number report actually practicing more interaction and communication with others. On the other hand, Figure 12.7 also shows that reports of working more carefully (fighting complacency) and being more aware of self and others do more-closely match earlier expectations. These results suggest that early intentions to behave differently with others in the workplace may be overly optimistic or naive. Many respondents actually favored only new behaviors that they could adopt passively or by themselves. "Stress Management" is an example of this trend toward individual and private action. Although too few AMT respondents specifically state that they will subsequently apply the lessons learned about managing stress to show in Figure 12.6, many do report acting more carefully and self-consciously in the months following training (Figure 12.7).

Being thorough, fighting complacency, being aware of one's own impulses and feelings and observing those of their colleagues -- all of these are useful behaviors that AMTs could do by themselves. But actually speaking up, or initiating work-related conversation with others is more difficult to do without having other, larger, changes occurring in the workplace. In particular such changes require the involvement of management in the MRM training.

Figure 12.7 also shows that reports of "no change" or negative comments about changing and/or the effects of the MRM training are quite high. In fact the combined percentage of "no change" and negative answers approaches 30 percent of the total for the 2-month and the 6-month surveys -- and the proportion of negative answers to the more neutral "no change" increases by nearly one-half between the 2- and 6-month surveys.

Raising AMT Participants' Expectations For MRM May Be A Problem.

If AMTs are pushed to the front of what is essentially a culture change, they then wonder where everybody else is -- and then get frustrated and/or discouraged when they don't see enough support. Despite positive trends apparent in this and other programs, there may not be enough continued action or management support for MRM. In particular the positive effects of these programs on attitudes and performance are often not widely or quickly available for diffusion to those company's participants. Increased involvement of the training's past participants in survey feedback and in ongoing safety initiatives and continued attempts to improve communication may counter the negative backlash observed in the preceding example. MRM training that becomes an exercise in mere "spray and pray," whether by intention or by accident, may sow the seeds of its own discontent. The ideas and behaviors are too liberating to expect participants to see them erode without reaction.

The big payoff for the commitment by company or trade union to MRM-style change is a culture that breeds continuous improvement in human effectiveness and airplane safety.

THE SIGNIFICANCE OF THIS RESEARCH

The primary benefit from this research is the timely documentation of significant effects of MRM programs as measured by positive changes in maintenance personnel attitudes and behaviors demonstrated over time and positive improvements in maintenance operations performance. Through this research the industry partners and general industry community are alerted to the best practices in current MRM and can determine what MRM elements are proving most successful in their own company and elsewhere. The secondary benefit of this program is to continue the development of a MRM training evaluation database, to confirm the importance of a longitudinal evaluation process and to provide information for future developments and improvements in such training and allied interventions for the end users.

The first product is the delivery of frequent data feedback to MRM program managers, sponsors, and facilitators to help them continuously improve their own programs. Such feedback may be face to face, telephonic, or by Email. It is usually accompanied by informal documentation. Such informal feedback is largely unscheduled, but is usually as frequent as data analysis and trend visibility will allow.

More definitive results and conclusions to improve MRM practice in the industry are documented for wider distribution. These reports represent a second tier of deliverables -- special reports prepared on a periodic basis for FAA and NASA, and for the aviation industry, on trends and effects observed from the data which can be used to improve practice in other MRM programs throughout the industry.

A third tier of deliverables includes methods and practices to assist airline companies and other users collect behavioral data, while maintaining the conditions required for reliability and validity of those data. Over the course of the program such methods are documented and transferred to the participating companies. Such data collection methods are, however, virtually useless without parallel methods of analysis and interpretation. Interpretive tools and algorithms will therefore accompany any data collection instruments delivered. Protocols and worksheets for capturing field observations are being developed. These tools will be distributed to selected end users, in draft form for further development. Final versions of the core survey questionnaire ("MRM/TOQ") and of ethnographic data collection forms will be made available to sponsors and end users.

The performance regarding injury and aircraft damage which are currently available may not be adequate for the future. Currently active discussion in the aviation industry is exploring a global error analysis and detection system. The collection of these more comprehensive data in more companies should be encouraged (whether they currently have an MRM program or not).

A report of in-process results and implications will be prepared at the end of each year's research (years two and three, 1998 and 1999). A major research report will be prepared at the completion of the funded period.

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