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TRAINING TO REDUCE AVIATION MAINTENANCE ERROR: ASSESSING MAINTENANCE RESOURCE MANAGEMENT PROGRAMS IN COMMERCIAL AVIATION

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Maintenance resource management (MRM) training is intended to integrate existing technical skills of maintenance employees with interpersonal skills/human factors knowledge to improve communication effectiveness & maintenance safety. The FAA suggests successful MRM training not only teaches error avoidance, but also the adoption of attitudes that support a safety culture. This coincides with FAA encouragement to incorporate systems theory into MRM training to put human factors issues in larger organizational context. Many programs currently use the MRM/TOQ survey to assess the impact of MRM training & its effectiveness in changing safety-related attitudes. Previous research has identified key factors in MRM/TOQ items & argued that the instrument has good reliability/validity; however, interrelationships among factors have not been closely examined, nor have there been systematic attempts to understand how these four critical areas of human factors training fit into aviation safety frameworks. With growing relevance of systems theory to aviation, MRM training assessments should be based in systems framework & MRM/TOQ results analyzed therein. The paper reviews MRM training in a commercial aviation organization from a systems perspective in order to improve training assessment & confirm reliability/validity of MRM/TOQ. Findings indicate revision of MRM/TOQ is necessary to accurately assess training; also present evidence to support using systems framework to evaluate MRM training. This work is part of ongoing programs at the National Center for Aviation Safety Research.

Development of MRM Training
In the aviation industry, successful organizational performance is often considered with respect to safety - the avoidance of accidents and incidents and the promotion of behaviors/organizational norms considered safe. While many organizations are concerned with employee safety, aviation is a “high-consequence” industry; that is, an industry in which the consequences of poor safety performance are far more significant and generally more public than in other industries (e.g., commercial aircraft disasters, maintenance damage to multi-million dollar equipment, stakeholder fatalities). Aviation organizations are thus significantly invested in identifying and appropriately measuring factors that may affect safety performance. Intra- and interpersonal human factors as significant sources of error have received increased scrutiny in recent years for their potential impact on aviation safety (Patankar and Taylor, 2008).

MRM training developed from existing CRM programs finding success during the 1980s (Taylor & Patankar, 2001). According to Taylor & Patankar, the first reported CRM program geared toward aviation maintenance workers began in November 1989; this and other programs eventually became known as MRM programs after the term “Maintenance Resource Management” was coined in 1992 (Taylor & Christensen, 1998). According to the FAA, MRM is a “process for improving communication, effectiveness and safety in aircraft maintenance operations” (2000, p. 6), and was developed to address “teamwork deficiencies within the aviation maintenance environment” (p. 6). A review of four generations of MRM programs by Taylor and Patankar (2001) demonstrates a pattern of changing interest in the focus on organizational system variables and longitudinal stability of post-training attitude and behavior changes. Fourth generation MRM programs are interested in gauging participant attitudes not only on directly safety-related issues (such as whether participants feel their work impacts passenger safety), but also on organizational context issues such as leadership and coworker interaction. This represents the incorporation of
applied psychological principles into awareness training for safety-critical attitudes and behaviors, in an industry in which the consequences of failure are quite literally disastrous. Research that assists the aviation industry in appropriately integrating these principles is essential to their continued adoption and efficacy.

**MRM Training Assessment**

Based on the development and goals of CRM training programs, the Cockpit Management Attitudes Questionnaire (CMAQ) was developed to assess flight crew attitudes regarding human factors issues (Helmreich, Foushee, Benson, & Russini, 1986). Just as MRM evolved from initial efforts involving flight crews, so too did evaluation methodologies for MRM training evolve from those initially created to assess flight crew changes following CRM. Taggart (1990) was among the first to adapt CRM evaluation methods for the maintenance environment, revising the CMAQ for use with aviation maintenance employees. This modification was called the Crew Resource Management/Technical Operations Questionnaire (CRM/TOQ); later renamed the Maintenance Resource Management/Technical Operations Questionnaire (MRM/TOQ).

Research on the CMAQ (Gregorich, Helmreich, & Wilhelm, 1990; Sherman, 1992) confirmed four constructs based on the survey items given to flight crews: communication/coordination, shared command responsibility, recognition of stress effects, and avoidance of interpersonal conflict; though the conflict avoidance factor is inconsistent in CRM data and discarded in subsequent analyses (Gregorich et al.). Aviation industry accident/incident reviews suggest that behaviors related to these four constructs underlie many of the human factors errors that have occurred. Additionally, these four constructs incorporate aspects of a systems approach to promoting safety, attempting to gauge alignment among organizational factors such as leadership with interpersonal factors such as communication and conflict avoidance. The CMAQ, and later, the MRM/TOQ were both designed to measure changes in these four attitude constructs prior to and immediately following resource management training.

Gregorich et al. (1990) ran confirmatory factor analyses across three different samples to confirm the factor structure of the CMAQ with flight crew employees. While an exploratory factor analysis for maintenance employees has been conducted by Taylor (2000b), this analysis found different results than those presented by Gregorich et al. (such as strong evidence for the conflict avoidance factor), increasing the level of ambiguity regarding the four factors that result from evaluations of resource management training. In addition to these findings, Taylor was not focused on details regarding the nature of the pre- and post-training attitude relationship, meaning the analyses done by Gregorich et al. with flight data have yet to be done using data from maintenance employees. Given the existing discrepancies between the general factor structures found for each sample, as well as knowledge of the prevalence of difference types of error for each sample, it makes sense to compare both flight and maintenance sample data to identify relevant similarities or differences between the two populations.

While these four attitude constructs have been assessed with maintenance employee samples, the relationships among the constructs have not yet been identified. The present study attempts to fill this gap by analyzing maintenance data from the MRM/TOQ to replicate the work of Gregorich et al. (1990). If their results regarding flight crew attitude differences following training can be recreated with data from maintenance employees, this may increase the generalizability of the Gregorich et al. findings and suggest key leverage points when implementing human factors initiatives in aviation (Block, 2008). Additionally, confirmatory factor analyses with a large sample should clarify the relationship among the MRM/TOQ items for each factor and the presence of the conflict avoidance factor for maintenance employees, as well as support its continued investigation with that population, even though published data regarding flight crews (e.g., Gregorich et al.) may not support this factor as a part of resource management or human factors training. The present study thus also hopes to provide support for the continued use of the MRM/TOQ to measure maintenance employee attitudes, as the MRM/TOQ is based on a tool initially created to measure flight crew attitudes. Consistent results for both flight crews and maintenance employees would add additional support for the MRM/TOQ.

**Participants & Design**

Data were collected from 1458 aviation maintenance employees from a major U.S. airline who had participated in MRM training within the last 14 months. The mean age of respondents was 49.74 years (SD = 8.03), mean years in maintenance at the target organization was 17.55 (SD = 7.07), and a majority of the participants were male (96.6%).

The MRM/TOQ is a 17-item questionnaire developed to measure the attitudes and intentions of participants in airline maintenance communication and safety training workshops (Taylor, 2000b). As mentioned previously, the
MRM/TOQ has been adapted for maintenance employees from the Cockpit Management Attitudes Questionnaire CMAQ; the attitude areas as measured by the CMAQ have been validated as predictors of outcome factors (expert performance ratings), suggesting attitudes as measured by the CMAQ (or, in this case, the MRM/TOQ) may be used to indicate performance outcomes (Helmreich & Foushee, 1993).

Participants were asked to complete the MRM/TOQ immediately before the class started, and again at the end of the day (immediately following training). This survey gathered information on the four attitude areas identified in the work of Taylor (2000a, 2000b) for MRM training, as well as information on individual demographics. The post-training questionnaire also collected responses on three general outcome items: 1) this training has the potential to increase aviation safety and crew effectiveness; 2) this training will be useful for others; and 3) this training is going to change behavior on the job.

Factor Comparisons
Confirmatory factor analyses (CFA) using LISREL were conducted for both the pre- and post-training data to ascertain if the four-factor structure (communication/coordination, relational supervision, recognition of stress effects, and conflict avoidance) described by Taylor (2000b) for maintenance employees using the MRM/TOQ is consistent with the present data sample. Results of the post-training factor analysis are presented in Table 1. For pre-MRM training data Taylor’s four-factor structure failed to converge when all items were included. Eliminating the weakest item (“A truly professional team member can leave personal problems behind when working”) allowed a four-factor structure to converge, but still indicated poor item loadings for the two remaining items related to “recognition of stress effects”. Complete elimination of the stress effects factor did not change the fit indices of the three remaining factors: root mean square error of approximation (RMSEA) = 0.046, Tucker-Lewis index = 0.98, and comparative fit index = 0.98.

For post-training data the initial four-factor solution converged, but again indicated poor item factor loadings (lambda values) for “recognition of stress effects”; the CFA procedure was re-run with a three-factor structure, and results of both analyses may be seen in Table 1. Eliminating the stress effects factor contributed to a slight improvement in the RMSEA (from 0.061 to 0.056); other fit indices were unchanged by the removal of this factor: Tucker-Lewis index = 0.98, and comparative fit index = 0.98. Although Gregorich et al. (1990) identified conflict avoidance as a fourth factor, and found instability in this factor (made up of two items: “maintenance personnel should avoid disagreeing with one another” and “it is important to avoid negative comments about the procedures and techniques of other team members”), the present study found the three-factor structure more consistent in both pre-training and post-training data. The data indicate the factor that should be eliminated is not conflict avoidance, but recognition of stress effects. In his sample of aviation maintenance employees, Taylor (2000b) similarly found conflict avoidance as a stable third factor, although he suggests a four-factor structure is present and appropriate for data collected with the MRM/TOQ.

Pre-Post Training Comparisons
To test whether the same pattern of significant pre- and post-training attitude changes would be found in the present data as was found by Gregorich et al. (1990), a repeated-measures ANOVA procedure was performed on each pair of pre- and post-training composite scores, including site location and type of maintenance job held by participants as potential interacting variables. This is similar to the cross-organization and cross-job title analyses conducted by Gregorich et al. Analysis showed a significant main effect of training for two of the four factors: communication/coordination ($F_{1,1249} = 4.48$, $p < 0.05$) and conflict avoidance ($F_{1,1249} = 17.42$, $p < 0.05$). Analysis of the remaining two factors showed marginally significant change following training: $F_{1,1249} = 3.12$, $p = 0.07$ for relational supervision; $F_{1,1249} = 3.75$, $p = 0.053$ for recognition of stress effects. These results, however, may be due more to the large sample size contributing to the liberality of the F-test rather than to the presence of meaningful post-training differences (e.g., the net change in the composite score on relational supervision from pre- to post-training is 0.54, slightly more than one-half of one scale point). None of the interactions for any of the four factors were significant.

According to Gregorich et al. (1990), if resource management training was successful there should be diminished response variation following training; and if training enhanced pre-existing attitudes, response variation is likely to have increased following training. To determine whether such a variance reduction had occurred in the present sample, a t-test for the difference between correlated variances (e.g., testing for heterogeneity of variance) (Gregorich et al., 1990; Ferguson, 1971; Howell, 2002) was computed for each pair of pre- and post-training factor
scores. Contrary to results obtained by Gregorich et al., only the relational supervision and conflict avoidance factors showed a significant change in variability following training, and both of those factors actually demonstrated increased variability following MRM training, rather than the anticipated decrease in mean variability. Prior to MRM training, the mean variability (calculated as the squared deviation from the mean; Howell, 2002) for the relational supervision factor was $s^2 = 18.55$; following training the mean variability was $s^2 = 20.00$ ($t_{1457} = -2.595$, $p < 0.01$). Prior to MRM training the mean variability for conflict avoidance was $s^2 = 4.98$; following training the mean variability for this factor was $s^2 = 5.89$ ($t_{1457} = -5.378$, $p < 0.001$).

Discussion
Attempts to confirm the four-factor structure identified by Taylor (2000b) and provide additional support for the use of the MRM/TOQ in assessing MRM training produced mixed results. While the conflict avoidance factor (characterized by the items “maintenance personnel should avoid disagreeing with one another” and “it is important to avoid negative comments about the procedures and techniques of other team members”) has been found to be inconsistent and under-identified in samples of flight crews (Gregorich et al., 1990), both Taylor (2000b) and the present study found consistent responses for this factor among maintenance employees. The reasons for this distinction between the two broad categories of aviation employees are unclear. Perhaps maintenance employees perceive interpersonal disagreements and procedural disagreements as highly similar types of conflict, whereas flight crews make a distinction between the two – this may cause the items to diverge and may contribute to inconsistent results for flight crews on this factor. Additionally, the format of conflict training for maintenance employees may differ in approach from that used with flight crews, leading to discrepancies in interpretation of this factor. Future research comparing flight crews and maintenance employees on human factors issues may wish to address this in greater depth.

The factor “recognition of stress effects” proved to be problematic in the present study. Although Taylor (2000b) found this factor to be consistent among maintenance employees in the air carriers he studied, the present work (which may not have included the same carriers) found little support for continued inclusion of this factor in its present state. Confirmatory factor analysis indicated a poor degree of item fit for the three items intended to measure stress recognition. Results would suggest that stress recognition as a factor be dropped from subsequent investigations using the MRM/TOQ. For the aviation industry, however, stress recognition is considered an important aspect of human factors knowledge that should be conveyed to employees—meaning it should not be discarded from future MRM research and training. The observed data on this factor strongly suggest that modifications are warranted for either 1) items used in the MRM/TOQ to measure understanding and agreement with stress recognition human factors training; or 2) the method of presentation of stress recognition information in the MRM courses. The data on this factor indicate a conceptual disconnect between the teaching of stress recognition as it is currently provided and the understanding of stress recognition as it is captured by the current MRM/TOQ. If the industry wishes to continue emphasizing the importance of stress recognition as a component of MRM training, the measurement methods for this factor and the training content must be in alignment.

The present study sought, in part, to identify whether maintenance employees respond to resource management training in a manner similar to that reported by Gregorich et al. (1990) for flight crews. Inter-item reliability for the items used in the MRM/TOQ factors was comparable to that reported by Gregorich et al. and Taylor (2000b), except for the factor “recognition of stress effects” (Cronbach’s $\alpha = 0.29$ in both pre- and post-training data). Of interest is the question of what constitutes “good” reliability. Both Gregorich et al. and Taylor report “acceptable” or “good” reliability for the items in each factor, with Cronbach’s alpha values ranging from 0.47 – 0.67 (Gregorich, et al.) and from 0.51 – 0.77 (Taylor). Generally, $\alpha$ levels above 0.70 are desired to indicate “good” reliability (as an $\alpha = 0.70$ would indicate slightly less than half of the variance in the item is attributable to measurement error). The reasons for the instability in this factor are unclear. Perhaps maintenance employees do not clearly perceive the relationship between the effects of stress and safety outcomes, perhaps the items are being misinterpreted, or maybe the material is not being clearly explained in the course of MRM training.

Gregorich et al. (1990) argued that successful resource management would be indicated not only by post-training attitude change, but also by diminished response variation following resource management training; otherwise, if training bolstered existing attitudes, response variability should increase post-training. While Gregorich et al. found that, as hypothesized, variability decreased following training, the present study found the opposite: for two of the four factors (relational supervision and conflict avoidance) variability significantly increased following MRM training. According to Gregorich et al., these findings would suggest that MRM training has not been completely
successful in changing important safety-related attitudes for maintenance employees. An alternative view may be
that, for the majority of maintenance employees, MRM training is changing attitudes in the desired direction (hence
the significant and near-significant post-training attitude changes); however, this is causing the gap between
employees who exhibit desired change and employees who “boomerang” following training to widen, which would
appear as greater variability in post-training responses.

Table 1: Post-Training Data Confirmatory Factor Analysis

<table>
<thead>
<tr>
<th>Four Factor Structure</th>
<th>Three Factor Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda )</td>
<td>( R^2 )</td>
</tr>
<tr>
<td><strong>Communication/Coordination</strong></td>
<td></td>
</tr>
<tr>
<td>Employees should make the effort to foster open, honest, and sincere communication.</td>
<td>0.89</td>
</tr>
<tr>
<td>We should always provide both written and verbal turnover to the oncoming shift.</td>
<td>0.86</td>
</tr>
<tr>
<td>My work impacts passenger satisfaction/safety.</td>
<td>0.88</td>
</tr>
<tr>
<td>A debriefing and critique of procedures and decisions after a significant task is completed is an important part of developing and maintaining effective crew coordination.</td>
<td>0.82</td>
</tr>
<tr>
<td>Having the trust and confidence of my coworkers is important.</td>
<td>0.76</td>
</tr>
<tr>
<td>Start of shift maintenance crew meetings are important for safety and for effective crew management.</td>
<td>0.72</td>
</tr>
<tr>
<td>My coworkers value consistency between words and actions.</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Relational Supervision</strong></td>
<td></td>
</tr>
<tr>
<td>My supervisor can be trusted.</td>
<td>0.84</td>
</tr>
<tr>
<td>My supervisor protects confidential or sensitive information.</td>
<td>0.79</td>
</tr>
<tr>
<td>Mechanics' ideas are carried up the line.</td>
<td>0.67</td>
</tr>
<tr>
<td>My suggestions about safety would be acted on if I expressed them to my lead or supervisor.</td>
<td>0.74</td>
</tr>
<tr>
<td>I know the proper channels to route questions regarding safety practices.</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>Conflict Avoidance</strong></td>
<td></td>
</tr>
<tr>
<td>It is important to avoid negative comments about the procedures and techniques of other team members.</td>
<td>0.75</td>
</tr>
<tr>
<td>Maintenance personnel should avoid disagreeing with one another.</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>Recognition of Stress Effects</strong></td>
<td></td>
</tr>
<tr>
<td>Even when fatigued, I perform effectively during critical phases of work.</td>
<td>0.05</td>
</tr>
<tr>
<td>Personal problems can adversely affect my performance.</td>
<td>-0.19</td>
</tr>
<tr>
<td>A truly professional team member can leave personal problems behind when working.</td>
<td>-0.25</td>
</tr>
</tbody>
</table>

With the exception of the overall factor structure and the analyses of response variability, the present study
confirmed that many of the characteristics found in samples of flight crews who have participated in CRM training
might also be found among maintenance employees who have participated in MRM training. This suggests that the
underlying principles of both CRM and MRM are contributing to attitude change with regard to human factors
issues. The differences in the consistency of the factor structure between flight crews and maintenance employees
may suggest that there are differences in the material emphasized for flight crews and the material emphasized for
maintenance employees (such that conflict avoidance is given more time/weight in MRM courses), that flight crews
and maintenance employees have different mental concepts for “conflict avoidance”, or that conflict avoidance is a
more relevant concept for maintenance employees. These differences in the order and consistency of the factor

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structure for these items suggest that there are different characteristics of the flight crew and maintenance populations, and that these differences should be taken into account when modeling attitude change, developing resource management training, or making comparisons on outcomes between the two groups. Future studies that capture the underlying concepts behind employees’ evaluations of both conflict avoidance and recognition of stress effects would help to clarify these discrepancies, and better explain the relationship between each of the four factors, general job area (flight crew or maintenance) and safety.

Acknowledgements
The authors are grateful to the Federal Aviation Administration for support of this research, conducted under grant #2003-G-013, Maintenance Aviation Safety Action Programs, Principal Investigator Dr. Manoj Patankar. The authors also wish to thank Dr. Matt Grawitch for his editorial guidance and insightful comments in the development of this research. This paper is based on a doctoral dissertation by E. Block.

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