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Development of a Commercial Aviation Safety Culture Survey for Maintenance Operations

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Abstract

This paper describes the development and validation of a survey to assess safety culture in airline maintenance operations according to the five-factor model of safety culture proposed by Wiegmann et al. (2002). This survey parallels the survey created for flight operations (Wiegmann et al., 2003). Maintenance technicians at two FAR Part 121 scheduled passenger airlines (N = 109 and 76) completed the original version of the survey. The results yielded useful diagnostic information about the safety culture of each airline, but factor analyses indicated that the five-factor model may not be adequate to describe the data. A more complex model is proposed and modifications to the survey are suggested.

Development of a Commercial Aviation Safety Culture Survey for Maintenance Operations

The Commercial Aviation Safety Survey (CASS) was developed as a means of assessing the overall safety culture within an airline. Survey methodology is cost-effective for large organizations, as data can be collected and analyzed quickly. While survey methods do not result in the same level of detail as more in-depth assessment strategies, such as individual interviews or direct observation, they offer the advantage of allowing a large proportion of the employee population to participate and to do so anonymously, without fear of negative repercussions from the organization.

The CASS was designed to measure five organizational indicators of safety culture, as identified in our previous review of the safety culture literature (Wiegmann, Zhang, von Thaden, Sharma, and Mitchell, 2002). These indicators, derived from common themes in safety culture research across industries, were as follows:

> *Organizational Commitment to Safety*: The degree to which upper management promotes safety, as evidenced by safety-related policies and the commitment of resources to maintain and improve safe operations.
>
> *Managerial Involvement in Safety*: The degree to which middle and lower-level managers are personally involved in safety activities and in promoting safety among their employees. (This dimension is labeled *Supervisory Involvement* in the maintenance survey, as front-line managers in maintenance are more commonly titled “supervisors”).
>
> *Employee Empowerment:* The degree to which employees are invited to participate in safety-related activities and decisions, and encouraged to take personal responsibility for safety.
>
> *Accountability System:* The degree to which the organization rewards safe behavior and dispenses consequences for unsafe behavior.
>
> *Reporting System:* The degree to which the organization possesses an effective, accessible means of reporting safety information that employees are willing to use.

Two versions of the CASS were created: one for flight operations personnel (pilots, chief pilots, and operations management) and one for aviation maintenance personnel (technicians, inspectors, lead technicians, supervisors, and maintenance management). The job functions and the safety-relevant behaviors of these two groups are quite different, so a single survey for both types of operations would only assess behavior in the most general terms. More specific surveys allow for a more precise identification of strong and weak areas.

The flight operations version of the CASS was created first, with items based on existing safety culture inventories from a number of industries. Wiegmann, von Thaden, Mitchell, Sharma, &

Zhang (2003) contains a detailed description of the development of the flight operations survey. The development of the maintenance survey is the focus of the present report. The maintenance version of the survey is designed to reflect the same structure as the flight operations version (that is, to measure the same five indicators of safety culture, plus an additional measure of respondents' perceptions of risk at the airline), but to use terminology and describe behavior appropriate to the maintenance function.

Maintenance Survey Development

The first step in the development process was to identify those items in the flight operations survey that would apply to maintenance operations with little or no modification. Of the 89 items on the flight operations survey, 38 met this criterion. These items, in both their original and reworded versions, appear in Table 1. Three additional items that had originally appeared in the Organizational Commitment scale in the flight operations version were moved to the Supervisory Involvement scale in the maintenance version, with few other changes. Several items from the flight operations survey were considered inappropriate for maintenance personnel as written, but could be rewritten to reflect the intent of the original item in a maintenance context. For example, the item "management expects pilots to push the weather" was replaced by the item "supervisors never pressure inspectors to sign-off on borderline work." Maintenance technicians are not at all likely to encounter the scenario described in the first item, but both items represent the same basic idea: a specific, common situation in which the responsible manager pressures a subordinate to behave in an unsafe manner. A total of 14 items were modified in this way (see Table 2).

Table 1. Items common to the flight operations and maintenance versions of the CASS.

Maintenance Survey Items	Flight Operations Survey Items
Accountability System Scale	
Action is consistently taken against technicians who violate safety procedures or rules	Action is consistently taken against pilots who violate safety procedures or rules.
Technicians are consistently held accountable for acting unsafely even if their actions saved time or money	Pilots are consistently held accountable for acting unsafely even if their actions saved time or money.
Maintenance technicians get little recognition for proposing new safety ideas	Pilots get little recognition for new safety ideas.
Standards of accountability are consistently applied to all technicians	Standards of accountability are consistently applied to all pilots in this airline.
When technicians make mistakes they are dealt with fairly by the company	When pilots make a mistake or do something wrong, they are dealt with fairly by the airline.
Employee Empowerment Scale	
Technicians look at the company record as their own and take pride in it	Pilots look at the airline's safety record as their own and take pride in it.
Supervisors rarely question a technician's	My airline rarely questions a pilot's decision to

decision to keep a plane in maintenance longer that originally scheduled	turn around due to weather.
Peer influence is effective at discouraging violations of operating procedures and maintenance regulations	Peer influence is effective at discouraging violations of operating procedures and flying regulations.
I am encouraged to stop maintenance related activities that are unsafe	I am encouraged to stop flight related activities that are unsafe.
It is important for me to comply with all safety standards if I am to keep the respect of other technicians in my company	It is important for me to fly safely if I am to keep the respect of other pilots in my airline.

Organizational Commitment Scale

Safety is identified as a core value in my company	Safety is identified as a “core value” in my airline.
Management does not show much concern for safety until there is an accident or incident	Management doesn’t show much concern for safety until there is an accident or incident.
Management is willing to invest time money and effort to improve airworthiness and operational safety	Management is willing to invest money and effort to improve safety.
Management is committed to updating tools and equipment used in aircraft maintenance (e.g. NDT equipment; diagnostic tools)	Management is committed to equipping aircraft with up-to-date technologies.
People in my company would rather cancel a flight than take a chance with whether or not maintenance has been performed safely	When it comes down to it, people in this airline would rather take a chance with safety than cancel a flight.
My company's maintenance manual and information system are kept up to date	My airline’s manuals are up to date.
My company is more concerned with making money than being safe	My airline is more concerned with making money than being safe.
Management views regulatory violations very seriously, even when they don't result in any apparent damage	Management views regulation violations very seriously, even when they don’t result in any apparent damage.
My company emphasizes airworthiness and operational safety during the interview and orientation process	Safety is emphasized by my airline during the interview and orientation process.
Training practices at my company are centered around operational and airworthiness safety	Training practices at my airline are centered around safety.
Maintenance checklists and procedures are easy to understand and use	Checklists and procedures are easy to understand.
Safety works until we are busy	Safety works until we are busy.
Management is receptive to learning about safety concerns	Management is receptive to learning about safety concerns. *
Results of FAA safety inspections are made available to technicians for review	Results of FAA safety inspections are made available to pilots for review and information. *
Management involvement in personnel and airworthiness issues has a high priority at my company	Management involvement in safety issues has a high priority at my airline. *

Reporting System Scale

Technicians do not report their own mistakes when they are not obvious	Pilots do not report their own mistakes when they are not obvious.
I am familiar with the system for formally reporting safety issues in my airline	I am familiar with the system for formally reporting safety issues in my airline.

Technicians who report their errors make a big mistake	Pilots who admit their errors make a big mistake.
My company's safety reporting system includes procedures for me to report safety deficiencies	This airline's safety program includes mechanisms for me to report safety deficiencies.
Maintenance technicians who raise safety concerns are seen as troublemakers	Pilots who raise safety concerns are seen as troublemakers.
It is best to remain anonymous when reporting safety concerns or safety violations	It is best to remain anonymous when reporting an unsafe condition or incident.
Technicians can report safety discrepancies without the fear of negative repercussions	Pilots can report safety discrepancies without the fear of negative repercussions.
When maintenance technicians report a safety problem, supervisors act quickly to correct safety issues	When a pilot reports a safety problem, management acts quickly to correct safety issues.
Supervisory Involvement Scale	
Supervisors often fail to recognize when maintenance technicians are engaging in unsafe practices	Management often fails to recognize when pilots are flying unsafely.
Maintenance supervisors closely monitor proficiency standards to ensure technicians are qualified to perform the assigned tasks	Flight Management closely monitors proficiency and currency standards to ensure pilots are qualified to fly their assigned flights.
Supervisors stop unsafe operations or activities	Management stops unsafe operations or activities.
Perceived Risk Scale	
My company is likely to be involved in an airworthiness incident that is maintenance related in the next 12 months	My airline is likely to be involved in an incident in the next twelve months
My company is likely to be involved in an airworthiness accident that is maintenance related in the next 12 months	My airline is likely to be involved in an accident in the next twelve months.

* - item was part of the Managerial Involvement scale on the flight operations survey.

Table 2. Items modified from the flight operations version to the maintenance version of the CASS.

Maintenance Survey Items	Flight Operations Survey Items
Accountability System Scale	
Making careless mistakes harms my reputation with fellow technicians.	Being the cause of an accident or incident would have an adverse effect on your reputation with fellow pilots.
Employee Empowerment Scale	
My supervisors ask my opinion before making decisions that affect the safety of my work	Pilots are seldom asked for input when airline procedures are developed or changed.
Unsafe behavior is considered unprofessional	Pilots who violate safety regulations upset other

by other technicians	pilots even when no harm has resulted.
Effective communication exists up/down the chain of command	There are good communications here about safety.
Organizational Commitment Scale	
Shift work and day-off scheduling policies at my company greatly contribute to stress and fatigue in technicians	It is hard for pilots here to maintain a consistent sleep schedule.
My company's operating procedures make it hard for people to follow health and safety standards.	Some safety procedures/rules are not really practical.
Unsafe behavior is not tolerated in my company.	Following safety procedures is consistently expected.
Management does not enforce standard operating procedure until something goes wrong.	As long as there is no accident, management doesn't care how the flight operations are performed.
My company ensures that tools and equipment (e.g. work stands, hydraulic power sources, electrical equipment) are regularly inspected, serviced, and are safe to use	I am confident that maintenance on aircraft is adequately performed and that aircraft are safe to operate.*
I am provided with appropriate information, equipment, tooling time, and parts to accomplish my job	I am confident that maintenance on aircraft is adequately performed and that aircraft are safe to operate.*
My company ensures that the environment (e.g., lighting, air conditioning, ventilation) is conducive to effective maintenance work	I am confident that maintenance on aircraft is adequately performed and that aircraft are safe to operate.*
Supervisory Involvement Scale	
Supervisors never pressure inspectors to sign-off on borderline work.	Management expects pilots to "push" the weather.
Supervisors set the example for following maintenance standards and ensure compliance.	Upper level management gets personally involved in safety activities.
Maintenance technicians are briefed on potential hazards associated with maintenance activities.	Pilots are kept informed of any changes that may affect safety.
Supervisors provide clear and precise feedback to technicians about their safety compliance.	Chief Pilots do not hesitate to contact pilots to discuss safety issues.
Perceived Risk Scale	
I am likely to be injured on the job in the next twelve months.	I am likely to be involved in an incident in the next twelve months.

No items in the Reporting System scale were modified.

* - A single item in the flight operations version was modified into three distinct items for the maintenance version.

One item from the flight operations version was expanded into multiple items because the analogous situations in maintenance operations could be interpreted in more than one way. The item "I am confident that maintenance on aircraft is adequately performed and that aircraft are safe to operate" refers to the airline's provision of the necessary physical resources for a pilot to

do his or her job safely. Maintenance technicians work with several types of physical equipment, so several items were written to reflect this:

> "My company ensures that tools and equipment (e.g. work stands, hydraulic power sources, electrical equipment) are regularly inspected, serviced, and are safe to use."
>
> "My company ensures that the environment (e/g/ lighting, air conditioning, ventilation) is conducive to effective maintenance work."
>
> "I am provided with appropriate information, equipment, tooling time, and parts to accomplish my job."

As one preliminary test of the flight operations survey had already been conducted at the time that the maintenance survey was being developed, general feedback from that test was incorporated into the revisions. Items identified as confusing or ambiguous to participants were excluded, as were items that did not appear to have clear parallels in maintenance operations. Excluded items appear in Table 3.

Table 3. Items in the flight operations version of the CASS deleted from the maintenance version.

Flight Operations Survey Items
Accountability System Scale
Being involved in an accident or incident, even if it was not your fault, would have an adverse effect on your career with this airline.
Airline management shows favoritism to certain pilots.
Pilots who cause accidents or incidents are not consistently held accountable for their actions.
Being involved in an accident or incident, even if it was not your fault, has an adverse effect on your reputation with fellow pilots.
Employee Empowerment Scale
Pilots are actively involved in identifying and resolving safety concerns.
The best pilots in the group expect other pilots to behave safely.
Management ensures that all pilots are responsible and accountable for safe flight operations.
Pilots are given sufficient opportunities to make suggestions regarding safety issues.
Pilots do all they can to prevent accidents.
Pilots try to get around safety requirements whenever they get a chance.
Pilots often encourage one another to work safely.

Organizational Commitment Scale

Training focuses more on minimum requirements for a check ride than on safety.
Management tries to get around safety requirements whenever they get a chance.
Personnel responsible for safety hold a high status in my airline.
My airline inappropriately uses the MEL (e.g. illegally, use when it would be better to fix aircraft).
Safety is always discussed during training at my airline.
Management's view is that not all accidents are preventable.
Management views FARs as a hindrance.
My airline does all it can to prevent accidents or incidents.
When an accident occurs, management always blames the pilot.
Pilots who are not feeling well or are tired are encouraged not to fly.
Management expects pilots to push for on time performance.
Personnel responsible for safety have the authority to implement changes.
My airline does not cut corners where safety is concerned.

Supervisory Involvement Scale

My airline only keeps track of major safety problems and overlooks routine ones.
My airline's safety department is doing a good job.
Safety standards are seldom discussed openly.
Management has a clear picture of the risks associated with flight operations.
Safety issues are assigned high priority in meetings in this airline.
Chief Pilots are unavailable when pilots need help.

Reporting System Scale

Pilots are willing to report information regarding safety violations, marginal aviator performance, or other unsafe behavior.
Safety issues raised by pilots are communicated regularly to all pilots in the airline.
Pilots often cover up a hard landing or a close call if they feel they can get away with it.
There is no point in reporting a near miss.
I am satisfied with the way this airline deals with safety reports.

Perceived Risk Scale

I am likely to be involved in an accident in the next twelve months.
Other employees agree with my opinions regarding the likelihood of an accident at this airline in the next twelve months.

Finally, additional items were chosen and/or written to fill in the gaps left by the excluded items. The original safety culture inventories used to create the flight operations version of the survey were consulted again, to see whether we had overlooked any items more appropriate for maintenance than for flight operations. This search yielded six items (see Table 4). Twenty new items were written based on consultation with a subject matter expert who possessed extensive

airline maintenance experience. He pointed out situations and attitudes common in such an environment that were not captured in the existing items . The new items appear in Table 5.

Table 4. New items added from original sources to maintenance version of the CASS.

New Maintenance Survey Items	Original Item & Source
Supervisory Involvement Scale	
Supervisors do not permit technicians to cut corners.	Command leadership permits "cutting corners" to get the job done. (Ciavarelli & Figlock, ????)
Supervisors are more concerned with safe maintenance than the flight schedule.	Supervisors seem more concerned about their production performance than safety performance. (Janssens, Brett, & Smith, 1995)
Organizational Commitment Scale	
My company has a reputation for quality maintenance and sets standards to maintain quality control.	My command has a reputation for high-quality performance; My command has established quality standards and strives to maintain quality control. (Ciavarelli & Figlock, ????)
Maintenance technicians are given enough training to perform their work safely.	Employees are given enough training to do their work tasks safely. (Bureau of Air Safety Investigation, 1996)
Our management climate promotes adherence to the highest possible safety standard	My command provides a positive command climate that promotes safe flight operations. (Ciavarelli & Figlock, ????)
Personnel turnover among technicians negatively impacts the organization's ability to provide quality maintenance	Loss of experienced personnel has negatively affected my command's ability to operate safely. (Ciavarelli & Figlock, ????)

Table 5. New items written for the maintenance version of the CASS.

Maintenance Survey Items
Accountability System Scale
The process taken to investigate possible unsafe maintenance behavior is fair.
The actions taken against technicians who engage in unsafe behavior are appropriate.
The actions taken against technicians who engage in unsafe behavior are effective in encouraging other technicians to behave safely.
Employee Empowerment Scale
Technicians are comfortable approaching supervisors about personal problems/illness.

Everyone routinely performs the operational checks after the work is completed.
Everyone routinely re-inspects each other's work or has someone inspect their work before return to service.
A technician who stops a job because of a concern about safety or airworthiness is always supported by other technicians.

Organizational Commitment Scale

My company has a clearly written set of Safety Operating Procedures.
Tool control, calibration, and equipment certification are closely monitored by my company.
My company has effective shift turn-over procedures.
My company provides technicians with adequate safety related training (e.g. first aid, HAZMAT, fire).
My company has a program that targets training deficiencies.

Supervisory Involvement Scale

Supervisors try to distribute the workload evenly among technicians.
Supervisors shield technicians from outside pressures (e.g. flight crews, dispatch).
Supervisors are often unhappy when technicians take time off for training.
Supervisors and technicians work together to improve safety performance.
Supervisors encourage teamwork whenever possible.

Reporting System Scale

Return to service aircraft documentation and record keeping is taken seriously at this company.
Management issues and failures are examined during the investigation of significant safety occurrences.

Perceived Risk Scale

I am willing to allow my family to fly in the aircraft that are serviced by this maintenance facility.

The final maintenance version of the survey contained 84 items. As in the flight operations version, respondents were instructed to use a 7-point Likert-type response scale to indicate their agreement or disagreement with each item. A rating of 1 indicated that the respondent "strongly disagree(d)" with the item and a rating of 7 indicated that he or she "strongly agree(d)." The center point of the rating scale, 4, was labeled "neither agree nor disagree." Space was provided beside each item for respondents to write comments if they chose.

Initial Results from Two Airlines

Maintenance personnel from two FAR Part 121 passenger airlines completed the survey. Surveys were distributed via each airline's mail system, along with a letter from the airline encouraging participation and a stamped addressed envelope so that participants could return surveys directly to the researchers. Participants were assured that their responses would remain confidential and

they were not asked to provide their names or other personally identifying information. No compensation was offered to participants or their organizations.

A total of 1148 surveys were distributed: 860 to employees of Airline A and 288 to Airline B. One hundred and nine of the Airline A surveys and 76 of the Airline B surveys were returned, for response rates of 13% and 26% respectively. At Airline A, most respondents (74%) described their primary job responsibility as "Aircraft Technician;" at Airline B, respondents were more evenly divided between technicians (40%) and supervisory positions (Line Manager, Lead Technician, Inspector, or Manager; 51% combined).

Scale Reliability

The reliability of the five dimension scales was assessed using the Guttman-Cronbach alpha coefficient (Cronbach, 1951; McDonald, 1999), which is based on the correlation between each item in a scale and the rest of the items. Scales in which all items are highly intercorrelated are said to be reliable. Values of the alpha coefficient range from zero to unity, with higher values indicating higher reliability. Alpha values obtained from both samples are presented in Table 6. All five scales appear to show acceptable levels of reliability. This indicates that the items in each scale are related, so it is appropriate to aggregate them into a single scale score for each dimension.

Table 6. Scale reliability.

Scale	# of items	Airline A alpha	Airline B alpha
Organizational Commitment	31	0.94	0.94
Supervisory Involvement	14	0.91	0.91
Accountability System	9	0.77	0.89
Employee Empowerment	12	0.81	0.74
Reporting System	10	0.81	0.87

Dimension Scores

Scores for each airline were calculated for each of the five dimensions of safety culture as the mean of participants' responses to the items in each dimension scale. Items indicating a negative safety culture (e.g., "My airline is more concerned with making money than being safe.") were reverse coded for this analysis so that higher scores always indicated a more positive safety culture. All responses were made using a 7-point Likert-type rating scale, so a mean score of 7 on a given dimension would represent an extremely positive view of the airline with respect to that dimension. Dimension scores for both airlines appear in Figure 1.

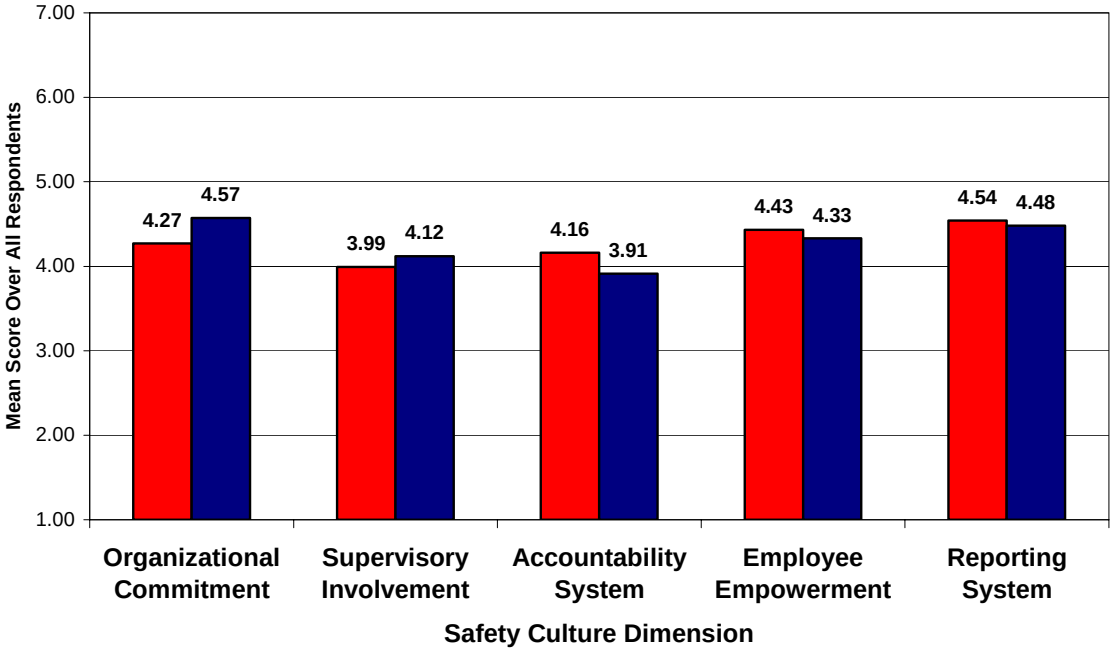


Figure 1. Dimension scores for both airlines.

Both of these airlines appear to have "middle-of-the-road" safety cultures, with scores near the neutral point (4.0) in most areas. However, the pattern of the dimension scores suggests different areas of strength and weakness for each airline, implying that the actual safety cultures experienced by employees are possibly quite different. Reporting systems are strong at both airlines; they are the strongest area at Airline A, while organizational commitment is Airline B's strongest dimension. Airline A needs improvement in supervisory involvement, while Airline B needs to improve its accountability system.

Analyses of individual item responses and respondent comments further support these overall impressions. At Airline A, most technicians were aware of their company's reporting system and willing to use it. However, they reported dissatisfaction with their supervisors' active involvement in and prioritization of safety issues. Lack of opportunities for safety-related training (categorized under "organizational commitment") also emerged as a potential problem. At Airline B, technicians believed that upper management's commitment to safety was sincere, but that first-level supervisors did not consistently enforce safety policies and that a "good ol' boys network" existed that hampered effective safety accountability. While the two airlines share many similarities, the survey allowed the identification of unique strengths and weaknesses, pinpointing specific areas in need of improvement.

Overall, the maintenance version of the CASS appears to be a useful diagnostic tool. The items can be grouped together into reliable scales to provide a broad-level picture of the organization or analyzed individually to identify specific strengths and weaknesses. The two types of analyses combined provide specific, useful information to airline management seeking to improve safety culture. Given the relatively low response rate for each airline, however, caution should be taken in interpreting these diagnostic assessments too liberally. More data would be required before making any major changes within either organization. Nonetheless, the number of surveys returned was sufficient to achieve the larger goal of this study, which was to test the five factor model of safety culture.

Factor Analysis of the Maintenance CASS

To validate the five-dimensional model of safety culture proposed above, we conducted confirmatory factor analyses using the Mx software package (Neale, 2002). The data from Airline A were used in the initial analyses, because the small sample size from Airline B was not sufficient to allow a test of the full model. The data from Airline B were used as a cross-validation sample for the revised versions of the individual factor scales. The first model tested was the one hypothesized: a five-factor solution with each item loading on the dimension it was intended to measure. This model fit the data poorly: $X^2_{2765} = 5660.27$, $p<.001$; RMSEA = .11. Bentler and Bonett's normed fit index (NFI) was .30; Tucker and Lewis' index (TLI) was .43, and McDonald and Marsh's relative non-centrality index (RNI; see Neale, Boker, Xie, & Maes, 2004 for definitions and citations for all fit indices) was .45. Models are generally considered to show good fit when these indices are at least .90 (McDonald & Ho, 2002). Further, 303 of the 2926 possible residual correlations (i.e., 10%) had absolute values greater than .15. Residuals greater than .10 generally indicate misfit.

One possibility for the poor fit of the five-factor model is that respondents did not discriminate between dimensions of safety culture when completing the survey, but rather based their responses on their overall perception of the safety culture as good or bad. If this is the case, a single-factor model in which all items simply reflect the overall positive or negative safety culture of the organization would fit well. The single-factor model also fit poorly, however: $X^2_{2774} = 5711.40$, $p<.001$; RMSEA = .11. In fact, the fit of the single-factor model was significantly poorer than that for the five-factor model, $\Delta X^2_9 = 51.14$, $p<.001$.

As the data could not be described by either the five-factor model or a single general factor, the dimension scales were analyzed individually to identify specific sources of misfit. A single-factor model was fit to each scale to determine whether the scale represented a unidimensional construct. Examination of residual correlations (the differences between the observed correlations and those predicted by the model) was used to identify problematic items or possible subfactors within a scale. If an item appeared to be confusing, ambiguous, or highly redundant with another item, it was excluded and the fit of the single-factor model tested again. Items that

shared high residual correlations and could be grouped logically (e.g., items related to training) were tested as separate factors.

Accountability system scale. The single-factor model for the accountability system scale showed acceptable fit: X^2_{27} = 32.93, p=.20; RMSEA = .05, NFI = .84, TLI = .95, RNI = .96. Two pairs of items showed large residuals (absolute value > .15). The first large residual occurred between:

> "Making careless mistakes harms my reputation with fellow technicians," (Item 14) and
>
> "Technicians are consistently held accountable for acting unsafely even if their actions saved time or money." (Item 23)

The observed correlation between these items was .01, indicating that the lack of relationship between the items created the large residual. Item 14 had only modest correlations with the other items in the accountability system scale (none above .28) and an item-total correlation of only .20. The reliability analysis indicated that removing item 14 from the scale would increase the value of the alpha coefficient. A model excluding item 14 also fit well, X^2_{20} = 21.46, p=.37; RMSEA = .03, but the difference between the fit of the revised and original models was not significant, ΔX^2_7 = 11.48, p=.12.

The other large residual occurred between:

> "The process taken to investigate possible unsafe maintenance behavior is fair," (Item 30) and
>
> "When technicians make mistakes they are dealt with fairly by the company." (Item 64).

These items were strongly correlated (r = .46) and appear to have overlapping content. Item 64 had, on average, lower correlations with the other items than did item 30, so a model excluding item 64 was tested. As before, the revised model showed good fit, X^2_{20} = 21.33, p=.38; RMSEA = .03, but was not a significant improvement over the original model, ΔX^2_7 = 11.60, p=.11.

Data from Airline B were used to cross-validate the single-factor model. Again, the model seemed to fit reasonably well, though not as well as with the Airline A data, X^2_{27} = 48.75, p=.01; RMSEA = .11. The fit indices also showed acceptable or near-acceptable fit (NFI = .87, TLI = .91, RNI = .94), and only 1 of the 45 residuals had an absolute value greater than .15. Of these, three were associated with item 26 ("Maintenance technicians get little recognition for proposing new safety ideas."). Removing this item significantly improved fit for the Airline B sample (ΔX^2_7 = 22.68, p < .01), but not for the Airline A sample (ΔX^2_7 = 1.93, p = .96).

Employee empowerment scale. The single factor model for the employee empowerment scale did not fit particularly well, X^2_{54} = 87.42, p<.01; RMSEA = .08, NFI = .73, TLI = .84, RNI = .87. An attempt to separate the items into two factors (authority to improve safety and technicians' safety

professionalism) based on large residuals and logical relationships among items yielded only slightly improved fit (X^2_{53} = 76.26, p = .02; RMSEA = .07) and a further division into three factors (authority, professionalism, and peer influence) did not fit better (X^2_{51} = 75.50, p = .01; RMSEA = .07). Consequently, an exploratory factor analysis (EFA) was conducted using the COFA software program (see McDonald, 1999) to investigate the structure of the scale. A three-factor model was tested first, because the three-factor model suggested above showed (though barely) the best fit of the three. The promax rotated solution identified three factors that are in many ways similar to the three factors suggested by conceptual grouping (see Table 7). The first factor appears to reflect supervisors' respect for technicians in safety matters (authority), the second seems to describe technicians' personal pride in upholding safety standards (professionalism), and the third indicates a peer culture that supports safety (peer influence).

In a confirmatory factor analysis, this model showed acceptable fit, X^2_{51} = 65.56, p = .08; RMSEA = .05. One conceptual difficulty remained in that item 31 ("Everyone routinely performs the operational checks after the work is completed") and item 40 ("Everyone routinely re-inspects each other's work or has someone inspect their work before return to service") were clearly similar in content, but loaded on different factors. However, item 40 had near-equal loadings (.26 and .25, respectively) on both the professionalism and peer culture factors. Moving this item to the peer culture factor actually slightly improved the fit of the model, X^2_{51} = 61.14, p = .16; RMSEA = .05. In the interest of parsimony, a second exploratory analysis was conducted requesting only two factors. The factors identified by the promax rotation were identical to those suggested by the conceptual two-factor grouping. As that model had already been shown to fit poorly, the three-factor model for the employee empowerment dimension was retained.

Table 7. Exploratory Factor Analysis for Employee Empowerment Items.

Conceptual factors suggested by residual matrix	Factors suggested by COFA
Authority	
1. Technicians are comfortable approaching supervisors about personal problems/ illness.	1. Technicians are comfortable approaching supervisors about personal problems/illness.
Supervisors rarely question a technician's decision to keep a plane in maintenance longer that originally scheduled.	Supervisors rarely question a technician's decision to keep a plane in maintenance longer that originally scheduled.
My supervisors ask my opinion before making decisions that affect the safety of my work.	My supervisors ask my opinion before making decisions that affect the safety of my work.
I am encouraged to stop maintenance related activities that are unsafe.	Effective communication exists up/down the chain of command.
Effective communication exists up/down the chain of command.	

Professionalism	
2. Technicians look at the company record as their own and take pride in it. *Everyone routinely performs the operational checks after the work is completed.* Everyone routinely re-inspects each other's work or has someone inspect their work before return to service.	2. Technicians look at the company record as their own and take pride in it. Everyone routinely re-inspects each other's work or has someone inspect their work before return to service. *I am encouraged to stop maintenance related activities that are unsafe.* *It is important for me to comply with all safety standards if I am to keep the respect of other technicians in my company.*
Peer Influence	
3. A technician who stops a job because of a concern about safety or airworthiness is always supported by other technicians. Peer influence is effective at discouraging violations of operating procedures and maintenance regulations. Unsafe behavior is considered unprofessional by other technicians. *It is important for me to comply with all safety standards if I am to keep the respect of other technicians in my company.*	3. A technician who stops a job because of a concern about safety or airworthiness is always supported by other technicians. Peer influence is effective at discouraging violations of operating procedures and maintenance regulations. Unsafe behavior is considered unprofessional by other technicians. *Everyone routinely performs the operational checks after the work is completed.*

Items in *italics* were assigned to different factors in the conceptual and exploratory groupings.

The three-factor model appeared to fit the cross-validation data from Airline B well, X^2_{51} = 45.54, p=.69; RMSEA = .00. However, some of the fit indices were inappropriately high, NFI = .75, TLI = 1.06, RNI = 1.05. This suggests empirical underidentification, a condition that occurs when the observed correlations between variables in a sample are near zero. This is most likely a function of the small Airline B sample size, but it prevents us from being able to draw conclusions about the cross-sample validity of the three-factor employee empowerment model.. There were five residuals with absolute values above .15, three of which were associated with item 21 (“Peer influence is effective at discouraging violations of operating procedures and maintenance regulations.”). This item had slight negative correlations with several other items, primarily those on the “authority” factor. However, removing this item did not resolve the identification problem.

Organizational commitment scale. The single-factor model did not fit the data well for the organizational commitment scale, X^2_{434} = 732.23, $p < .01$; RMSEA = .08, NFI = .55, TLI = .73, RNI = .75. Of the 465 residual correlations, ninety-nine were greater than .10, with 34 greater

than .15. This suggests that a multi-factor model is necessary to describe the items in this scale – such pervasive residuals are not likely to be resolved by removing a few items. To identify a starting point for conceptually grouping these items, we looked to the parallel analysis that had previously been conducted for the flight operations version of the survey. That investigation used an exploratory factor analysis to identify three factors: perceived attitude of upper management toward safety, use of preventive safety practices (such as safety training, maintenance, and clear procedures), and commitment of organizational resources (money, time, and personnel) to safety. The items for the maintenance survey were correspondingly grouped into similar factors and a three-factor model was tested. However, that model showed only small (but significant) improvement in fit over the single-factor model, $X^2_{431} = 704.48$, $p = .00$; RMSEA = .08. The number of residuals greater than .10 increased to 106, with 33 residuals above .15.

An exploratory factor analysis was again conducted using COFA. A three-factor solution was initially requested, but only two items loaded on one of the resulting factors. A two-factor solution was then tested. The two factors appeared to generally cluster around management attitude items (e.g., “Unsafe behavior is not tolerated in my company.”) and resource items (e.g., “Tool control, calibration, and equipment certification are closely monitored by my company.”). Subsequent confirmatory analysis indicated that this model fit considerably better than the previous models, $X^2_{433} = 653.53$, $p = .00$; RMSEA = .07, but it still had 25 residuals greater than .15. A third EFA was conducted, this time requesting a four-factor solution. Again, factors for management attitude and resources were present, with a new factor appearing for items related to training (e.g., “Training practices at my company are centered around operational and airworthiness safety.”). The fourth factor contained only three items:

> “Results of FAA safety inspections are made available to technicians for review” (Item 17),
>
> “My company ensures that the environment (e/g/ lighting, air conditioning, ventilation) is conducive to effective maintenance work” (Item 29), and
>
> “Shift work and day-off scheduling policies at my company greatly contribute to stress and fatigue in technicians.” (Item 39).

Items 17 and 29 were the two items that had previously loaded on the third factor in the first EFA. Upon examination of the items, no conceptual relationship between the three is readily apparent, except perhaps that all are rather indirect assessments of safety culture. Respondents may have viewed these items as less relevant to the purpose of the survey and responded accordingly. In confirmatory analysis, the four factor model showed the best fit so far, $X^2_{399} = 550.69$, $p = .00$; RMSEA = .06, with 21 residuals greater than .15. Fit indices for this model approached acceptable levels, NFI = .69, TLI = .88, RNI = .89.

As the fourth factor described above was not clearly interpretable and may have simply consisted of poor items (i.e., items that were perceived as irrelevant), another confirmatory analysis was conducted excluding those three items (and thus the fourth factor). This new three-factor model (consisting of attitude, resource, and training factors) did not yield a significant improvement in fit over the four-factor model (X^2_{321} = 475.63, p = .00; RMSEA = .07, ΔX^2_{78} = 75.05, p=.57). However, in the revised model, it became apparent that many of the large residuals were associated with item 10 ("Management is committed to updating tools and equipment used in aircraft maintenance (e.g. NDT equipment; diagnostic tools)."). Excluding this item from the new three-factor model resulted in a significant improvement in fit for that model (X^2_{296} = 421.30, p = .00; RMSEA = .07, ΔX^2_{25} = 54.33, p<.01), and the resulting model also fit significantly better than the four-factor model (ΔX^2_{103} = 129.38, p=.04). Fit indices for this model were similar to those for the four-factor model, NFI = .72, TLI = .88, RNI = .89. Eight large (> .15) residuals remained, but no item was connected with more than one of these, and no logical connections between pairs of items sharing large residuals were apparent.

A five factor model was also tested in an attempt to see whether the model described above could be improved upon. However, a confirmatory test of that model did not fit as well as the four-factor model (X^2_{395} = 562.95, p = .00; RMSEA = .07), so no further tests of that model were conducted. The revised three-factor model (attitude, resources, and training) was retained.

Again, data from Airline B were used to cross-validate the revised model. The three-factor model did not fit particularly well, X^2_{296} = 480.08, p = .00; RMSEA = .10, NFI = .61, TLI = .77, RNI = .79. This suggests that these factors should be used with caution in future research, as they may reflect idiosyncratic characteristics of Airline A rather than the general structure of organizational commitment across airlines.

Reporting system scale. The single factor model showed acceptable fit for the reporting system scale, X^2_{35} = 42.63, p = .18; RMSEA = .05, NFI = .85, TLI = .96, RNI = .97. Low correlations between item 9 ("Management issues and failures are examined during the investigation of significant safety occurrences.") and item 50 ("It is best to remain anonymous when reporting safety concerns or safety violations.") and between item 20 ("I am familiar with the system for formally reporting safety issues in my airline.") and item 25 ("Technicians who report their errors make a big mistake.") resulted in high residuals (> .15) for those pairs of items. However, as both items had high correlations with the other items in the scale and the overall fit of the model was good, they were retained.

However, in the cross-validation sample from Airline B, the single-factor model did not fit as well, X^2_{35} = 70.13, p = .00; RMSEA = .12, NFI = .75, TLI = .81, RNI = .85. The large residuals observed in the Airline A sample between items 9 and 50 and 20 and 25 were not present in the Airline B sample, though 5 residuals with absolute values greater than .15 were present. Three of these were associated with item 20, which had particularly high correlations with item 9, item 38 ("My company's safety reporting system includes procedures for me to report safety

deficiencies."), item 58 ("Return to service aircraft documentation and record keeping is taken seriously at this company."). Removing item 20 improved the fit of the model in the Airline B sample, $X^2_{27} = 49.86$, $p = .01$; RMSEA = .11, $\Delta X^2_8 = 20.26$, $p < .01$, NFI = .80, TLI = .86, RNI = .89. Removing item 20 from the Airline A data improved the fit slightly, but not significantly, in that sample, $X^2_{27} = 33.54$, $p = .18$; RMSEA = .05, $\Delta X^2_8 = 9.10$, $p = .33$.

Supervisory involvement scale. The initial single factor model did not quite fit the supervisory involvement scale well, $X^2_{77} = 108.78$, $p = .01$; RMSEA = .07, NFI = .83, TLI = .93, RNI = .94. Examination of the residual matrix indicated that a large number of the discrepancies were related to item 44 ("Supervisors often fail to recognize when maintenance technicians are engaging in unsafe practices.") and item 56 ("Supervisors are often unhappy when technicians take time off for training."). Respondent comments on the item 56 indicated that technicians as well as supervisors disliked the productivity losses that occurred when other technicians were in training, so this item may not have been a good indicator of supervisors' safety attitudes. It was not immediately clear why item 44 should not function in the same way as other items in the scale. Removing item 56 improved the fit of the model substantially compared to the single-factor model containing all items, but did not yield acceptable fit, $X^2_{65} = 87.70$, $p = .03$; RMSEA = .06; $\Delta X^2_{12} = 21.08$, $p = .05$. Removing item 44 further improved the fit of the model, so that the model containing twelve items fit acceptably, $X^2_{54} = 63.59$, $p = .17$; RMSEA = .04; $\Delta X^2_{11} = 24.11$, $p = .01$, NFI = .85, TLI = .95, RNI = .96.

In the Airline B sample, the fit of the twelve-item model was similar, but not quite so good, $X^2_{54} = 84.73$, $p < .01$; RMSEA = .09, NFI = .80, TLI = .90, RNI = .92.

Revised model overall fit. The complete list of retained items, regrouped as described above, appears in Table 8. The new model contains a total of nine factors, as the organizational commitment and employee empowerment scales were each divided into three factors. The original survey contained seventy-six items, but seven items were deleted in the revision process, so the revised model contained only sixty-nine. Comparison of fit statistics for the original, final, and cross-validation models appears in Table 9.

Table 8. Retained and regrouped items based on factor analysis of Airline A.

	Maintenance Survey Items
	Accountability System Scale
6.	Action is consistently taken against technicians who violate safety procedures or rules.
14.	Making careless mistakes harms my reputation with fellow technicians.
23.	Technicians are consistently held accountable for acting unsafely even if their actions saved time or money.
26.	Maintenance technicians get little recognition for proposing new safety ideas.
30.	The process taken to investigate possible unsafe maintenance behavior is fair.

36. The actions taken against technicians who engage in unsafe behavior are appropriate.
48. Standards of accountability are consistently applied to all technicians.
51. The actions taken against technicians who engage in unsafe behavior are effective in encouraging other technicians to behave safely.
64. When technicians make mistakes they are dealt with fairly by the company.

Employee Empowerment Scale

Authority

12. Technicians are comfortable approaching supervisors about personal problems/illness
16. Supervisors rarely question a technician's decision to keep a plane in maintenance longer that originally scheduled
33. My supervisors ask my opinion before making decisions that affect the safety of my work
67. Effective communication exists up/down the chain of command

Professionalism

2. Technicians look at the company record as their own and take pride in it
55. I am encouraged to stop maintenance related activities that are unsafe
73. It is important for me to comply with all safety standards if I am to keep the respect of other technicians in my company

Peer Culture

11. A technician who stops a job because of a concern about safety or airworthiness is always supported by other technicians
21. Peer influence is effective at discouraging violations of operating procedures and maintenance regulations
31. Everyone routinely performs the operational checks after the work is completed
40. Everyone routinely re-inspects each other's work or has someone inspect their work before return to service
43. Unsafe behavior is considered unprofessional by other technicians

Organizational Commitment Scale

Management Attitude toward Safety

1. Safety is identified as a core value in my company
4. Management does not show much concern for safety until there is an accident or incident
5. Management is willing to invest time money and effort to improve airworthiness and operational safety
7. Management is receptive to learning about safety concerns
18. My company has a clearly written set of Safety Operating Procedures
22. Unsafe behavior is not tolerated in my company
24. My company has a reputation for quality maintenance and sets standards to maintain quality control
32. My company is more concerned with making money than being safe
47. Management does not enforce standard operating procedure until something goes wrong
53. Management views regulatory violations very seriously, even when they don't result in any apparent damage
59. Our management climate promotes adherence to the highest possible safety standard
62. My company's operating procedures make it hard for people to follow health and safety standards
72. Safety works until we are busy

Proactive Safety

13. People in my company would rather cancel a flight than take a chance with whether or not maintenance has been performed safely
28. My company ensures that tools and equipment (e.g. work stands, hydraulic power sources, electrical equipment) are regularly inspected, serviced, and are safe to use
34. My company has effective shift turn-over procedures
37. My company's maintenance manual and information system are kept up to date
41. I am provided with appropriate information, equipment, tooling time, and parts to accomplish my job
49. Tool control, calibration, and equipment certification are closely monitored by my company
69. Maintenance checklists and procedures are easy to understand and use

Safety Training

35. Maintenance technicians are given enough training to perform their work safely
57. My company provides technicians with adequate safety related training (e.g. first aid, HAZMAT, fire)
63. My company emphasizes airworthiness and operational safety during the interview and orientation process
65. Training practices at my company are centered around operational and airworthiness safety
66. Management involvement in personnel and airworthiness issues has a high priority at my company
70. My company has a program that targets training deficiencies

Reporting System Scale

9. Management issues and failures are examined during the investigation of significant safety occurrences.
15. Technicians do not report their own mistakes when they are not obvious.
20. I am familiar with the system for formally reporting safety issues in my airline.
25. Technicians who report their errors make a big mistake.
38. My company's safety reporting system includes procedures for me to report safety deficiencies.
45. Maintenance technicians who raise safety concerns are seen as troublemakers.
50. It is best to remain anonymous when reporting safety concerns or safety violations.
58. Return to service aircraft documentation and record keeping is taken seriously at this company.
68. Technicians can report safety discrepancies without the fear of negative repercussions.
75. When maintenance technicians report a safety problem, supervisors act quickly to correct safety issues.

Supervisory Involvement Scale

3. Supervisors try to distribute the workload evenly among technicians
8. Supervisors do not permit technicians to cut corners.
19. Supervisors shield technicians from outside pressures (e.g. flight crews, dispatch).
27. Supervisors never pressure inspectors to sign-off on borderline work.
46. Supervisors and technicians work together to improve safety performance.
52. Supervisors set the example for following maintenance standards and ensure compliance.
54. Supervisors provide clear and precise feedback to technicians about their safety compliance.
60. Supervisors encourage teamwork whenever possible.

61.	Maintenance supervisors closely monitor proficiency standards to ensure technicians are qualified to perform the assigned tasks.
71.	Maintenance technicians are briefed on potential hazards associated with maintenance activities.
74.	Supervisors stop unsafe operations or activities.

Table 9. Comparison of fit indices for original and revised dimension scales.

Index	Original Model Airline A	Final Model Airline A	Final Model Airline B
Accountability System Scale			
X^2	32.93	N/A	48.75
df	27		27
p	.20		.01
RMSEA	.05		.11
NFI	.84		.87
TLI	.95		.91
RNI	.96		.94
% resid. > .15	4%		2%
Employee Empowerment Scale			
X^2	87.42	61.14	45.54*
df	54	51	51*
p	<.01	.16	.69*
RMSEA	.08	.05	.00*
NFI	.73	.81	.75*
TLI	.84	.95	1.06*
RNI	.87	.96	1.05*
% resid. > .15	8%	4%	6%*
Organizational Commitment Scale			
X^2	732.23	421.30	480.08
df	434	296	296
p	<.01	<.01	<.01
RMSEA	.08	.07	.10
NFI	.55	.72	.61
TLI	.73	.88	.77
RNI	.75	.89	.79
% resid. > .15	7%	2%	8%
Reporting System Scale			
X^2	42.63	33.54	49.87
Df	35	27	27
p	.18	.18	.01
RMSEA	.05	.05	.11
NFI	.85	.86	.80
TLI	.96	.96	.86
RNI	.97	.97	.89
% resid. > .15	4%	2%	4%
Supervisory Involvement Scale			
X^2	108.78	63.59	84.73
df	77	54	54
p	.01	.17	<.01
RMSEA	.07	.04	.09
NFI	.83	.85	.80
TLI	.93	.95	.90
RNI	.94	.96	.92
% resid. > .15	4%	3%	3%

A confirmatory factor analysis was conducted to test the fit of the revised model. Again, however, the full model did not fit particularly well, $X^2_{2246} = 4099.49$, $p < .01$; RMSEA = .10. The normed fit index was .38, the Tucker-Lewis index was .54, and the relative non-centrality index was .56. While these values represent an improvement in fit compared to the original model (see Table 10 for a comparison), they still fall far short of acceptable levels. Of the 2415 residuals, 231 (9.6%) had absolute values above .15.

Table 10. Comparison of fit indices for original and revised overall models.

Index	Original Model Airline A	Final Model Airline A	Original Model – Only Final Items Airline A
Overall			
X^2	5660.30	4099.49	4236.75
df	2675	2246	2267
p	<.01	<.01	<.01
RMSEA	.11	.10	.10
NFI	.30	.38	.36
TLI	.43	.54	.52
RNI	.45	.56	.54
% resid. > .15	10%	10%	9%

To determine whether the observed improvement in fit was due to the regrouping of items or merely to the elimination of poor items, an additional confirmatory factor analysis was conducted using only the sixty-nine items in the revised model but grouping them into the original five factors. Again, this model fit poorly overall, $X^2_{2267} = 4236.75$, $p < .01$; RMSEA = .10. The fit of the revised (nine-factor) model was significantly better than that of this five-factor model, $\Delta X^2_{21} = 137.26$, $p < .01$, but comparison of the other fit indices (see Table 10) suggests that future improvements are possible.

Conclusions

While the results of the factor analysis generally supported the accountability system, reporting system, and supervisory involvement factors, the organizational commitment and employee empowerment factors remained problematic, and even the revised complete model did not show a good fit to the data. These findings are consistent, however, with the findings of the corresponding analysis of the flight operations survey. That survey also indicated a need to divide organizational commitment and employee empowerment into three subfactors each, and the subfactors identified in that analysis correspond conceptually in many ways to the subfactors identified here. For example, for the pilot empowerment scale, the factors that emerged were titled “Pilot Input,” “Peer Influence,” and “Pilot Responsibility/ Commitment.” In the

maintenance version, the factors were titled “Authority (to improve safety),” “Peer Influence,” and “Professionalism.” Similarly, in the flight operations version of the organizational commitment scale, the factors were titled “Organizational Attitude,” “Preventive Safety,” and “Resource Commitment to Safety,” while the factors in the maintenance version were called “Management Attitude,” “Proactive Safety,” and “Safety Training.” A direct comparison of the items in each subfactor can be seen in Table 11. The correspondence is certainly not exact, but these findings do suggest two conclusions: (1) While the accountability system, reporting system, and management/supervisory involvement scales appear to represent well-defined, unitary constructs, the pilot/employee empowerment and organizational commitment scales represent more complex phenomena that require further consideration; and (2) within those two scales, several consistent themes emerge that provide insight into how those constructs might be better defined in future.

Table 11. Comparison of new factors in the flight operations and maintenance surveys.

Flight Operations (revised survey)	Maintenance (revised survey)
Pilot/Employee Empowerment Scale	
Pilot Input	*Authority*
1. Pilots are seldom asked for input when airline procedures are developed or changed (R) Pilots are actively involved in identifying and resolving safety concerns Pilots are given sufficient opportunities to make suggestions regarding safety issues	1. Technicians are comfortable approaching supervisors about personal problems/illness. Supervisors rarely question a technician's decision to keep a plane in maintenance longer that originally scheduled. My supervisors ask my opinion before making decisions that affect the safety of my work. Effective communication exists up/down the chain of command.
Pilot Responsibility/Commitment	*Professionalism*
2. Management ensures that all pilots are responsible and accountable for safe flight operations. Pilots do all they can to prevent accidents. Pilots try to get around safety requirements whenever they get a chance (R).	2. Technicians look at the company record as their own and take pride in it. Everyone routinely re-inspects each other's work or has someone inspect their work before return to service. *I am encouraged to stop maintenance related activities that are unsafe.* *It is important for me to comply with all safety standards if I am to keep the respect of other technicians in my company.*
Peer Influence	*Peer Influence*
3. Pilots look at the airline's safety record as their own and take pride in it.	3. A technician who stops a job because of a concern about safety or airworthiness is

Pilots who violate safety regulations upset other pilots even when no harm has resulted.
Peer influence is effective at discouraging violations of operating procedures and flying regulations.
It is important to fly safely if I am to keep the respect of other pilots in my airline.
Pilots often encourage one another to work safely.
always supported by other technicians.
Peer influence is effective at discouraging violations of operating procedures and maintenance regulations.
Unsafe behavior is considered unprofessional by other technicians.
Everyone routinely performs the operational checks after the work is completed.

Organizational Commitment Scale

Organizational Attitude

1. Mgt doesn't show much concern for safety until there is an accident or incident (R).
   Safety is identified as a core value in my airline.
   Management expects pilots to push the weather (R).
   Management tries to get around safety requirements whenever they get a chance (R).
   My airline is more concerned with making money than being safe (R).
   My airline inappropriately uses the MEL (e.g. illegally, use when it would be better to fix aircraft) (R).
   Management's view is that not all accidents are preventable (R).
   Management views FARs as a hindrance (R).
   When an accident occurs, management always blames the pilot (R).
   Management expects pilots to push for on time performance, even if it means compromising safety (R).
   When it comes down to it, people in this airline would rather take a chance with safety than cancel a flight (R).
   Some safety procedures/rules are not really practical (R).
   My airline does not cut corners where safety is concerned.

Management Attitude toward Safety

1. Safety is identified as a core value in my company.
   Management does not show much concern for safety until there is an accident or incident.
   Management is willing to invest time money and effort to improve airworthiness and operational safety.
   Management is receptive to learning about safety concerns.
   My company has a clearly written set of Safety Operating Procedures.
   Unsafe behavior is not tolerated in my company.
   My company has a reputation for quality maintenance and sets standards to maintain quality control.
   My company is more concerned with making money than being safe.
   Management does not enforce standard operating procedure until something goes wrong.
   Management views regulatory violations very seriously, even when they don't result in any apparent damage.
   Our management climate promotes adherence to the highest possible safety standard.
   My company's operating procedures make it hard for people to follow health and safety standards.
   Safety works until we are busy.

Preventive Safety

2. Training focuses more on minimum requirements for a check ride than on

Proactive Safety

2. People in my company would rather cancel a flight than take a chance with

safety (R). Checklists and procedures are easy to understand. My airline's manuals are up to date. Management views regulation violations very seriously, even when they don't result in any serious damage. Safety is always discussed during training at my airline. Safety is emphasized by my airline during the interview and orientation process.	whether or not maintenance has been performed safely. My company ensures that tools and equipment (e.g. work stands, hydraulic power sources, electrical equipment) are regularly inspected, serviced, and are safe to use. My company has effective shift turn-over procedures. My company's maintenance manual and information system are kept up to date. I am provided with appropriate information, equipment, tooling time, and parts to accomplish my job. Tool control, calibration, and equipment certification are closely monitored by my company. Maintenance checklists and procedures are easy to understand and use.
Resource Commitment to Safety 3. Management is willing to invest money and effort to improve safety It is hard for pilots here to maintain a consistent sleep schedule (R) My airline does all it can to prevent accidents or incidents. Management is committed to equipping aircraft with up-to-date technology Pilots who are not feeling well or are tired are encouraged not to fly Personnel responsible safety have authority to implement changes	*Safety Training* 3. Maintenance technicians are given enough training to perform their work safely. My company provides technicians with adequate safety related training (e.g. first aid, HAZMAT, fire). My company emphasizes airworthiness and operational safety during the interview and orientation process. Training practices at my company are centered around operational and airworthiness safety. Management involvement in personnel and airworthiness issues has a high priority at my company. My company has a program that targets training deficiencies.

Specifically, the concept of employee (or pilot) empowerment seems to encompass several distinct elements: the authority granted to employees by the organization, the authority and personal responsibility assumed by employees, and the positive or negative impacts of the peer culture regarding safety. With respect to organizational commitment, respondents in both flight operations and maintenance appeared to distinguish between the “talk” (statements and policies) and the “walk” (actions and commitment of resources) of their organizations. While the two are not necessarily opposed, our results indicate that they are not necessarily connected either. Safety training was an area of greater emphasis for the maintenance respondents than for the flight

operations respondents, but the original maintenance version of the survey contained more training-related items than did the flight operations survey, so it is difficult to make a direct comparison.

The analysis of the flight operations survey concluded with a conceptual revision of the scale, based on input from the factor analysis and from respondent comments. An overview of the new survey structure for flight operations appears in Figure 2. Organizational commitment was divided into three subfactors, and the pilot empowerment subfactors were linked with the accountability system factor as aspects of an "Informal Safety System" second-order factor. The management involvement factor was divided to reflect different management personnel (e.g., chief pilots, dispatch) with whom pilots might interact, and the reporting system was similarly divided to indicate different parts of the reporting process. Given the strong conceptual similarity between the flight operations analysis and the results reported here, we considered whether a similar structure could be adopted for the maintenance survey. Again, we considered respondents' comments as well as the factor analyses to identify problematic items or areas of concern to technicians that might have been overlooked in the original survey. The revised model for maintenance appears in Figure 3.

Figure 2. Revised model for flight operations survey.

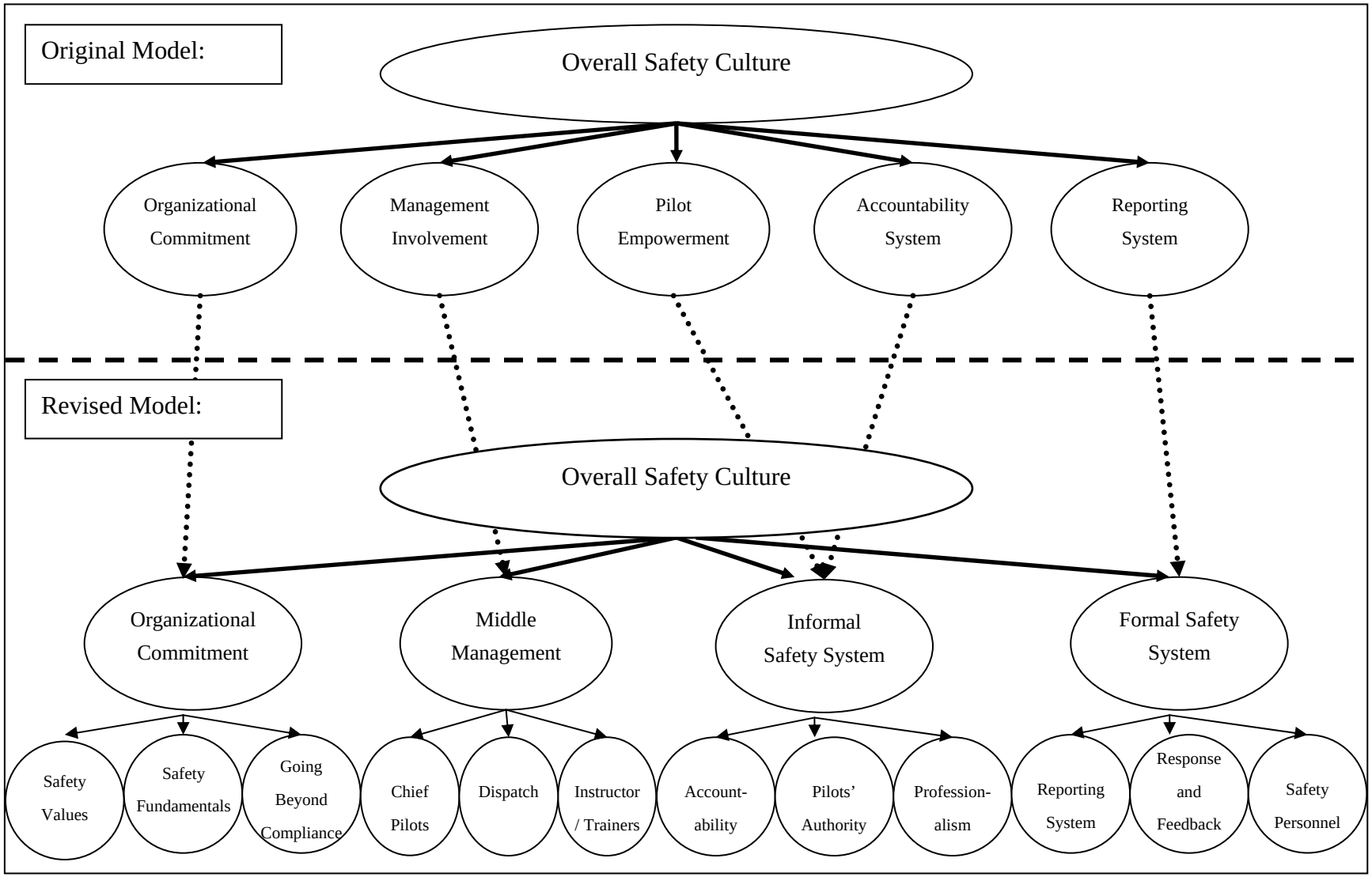
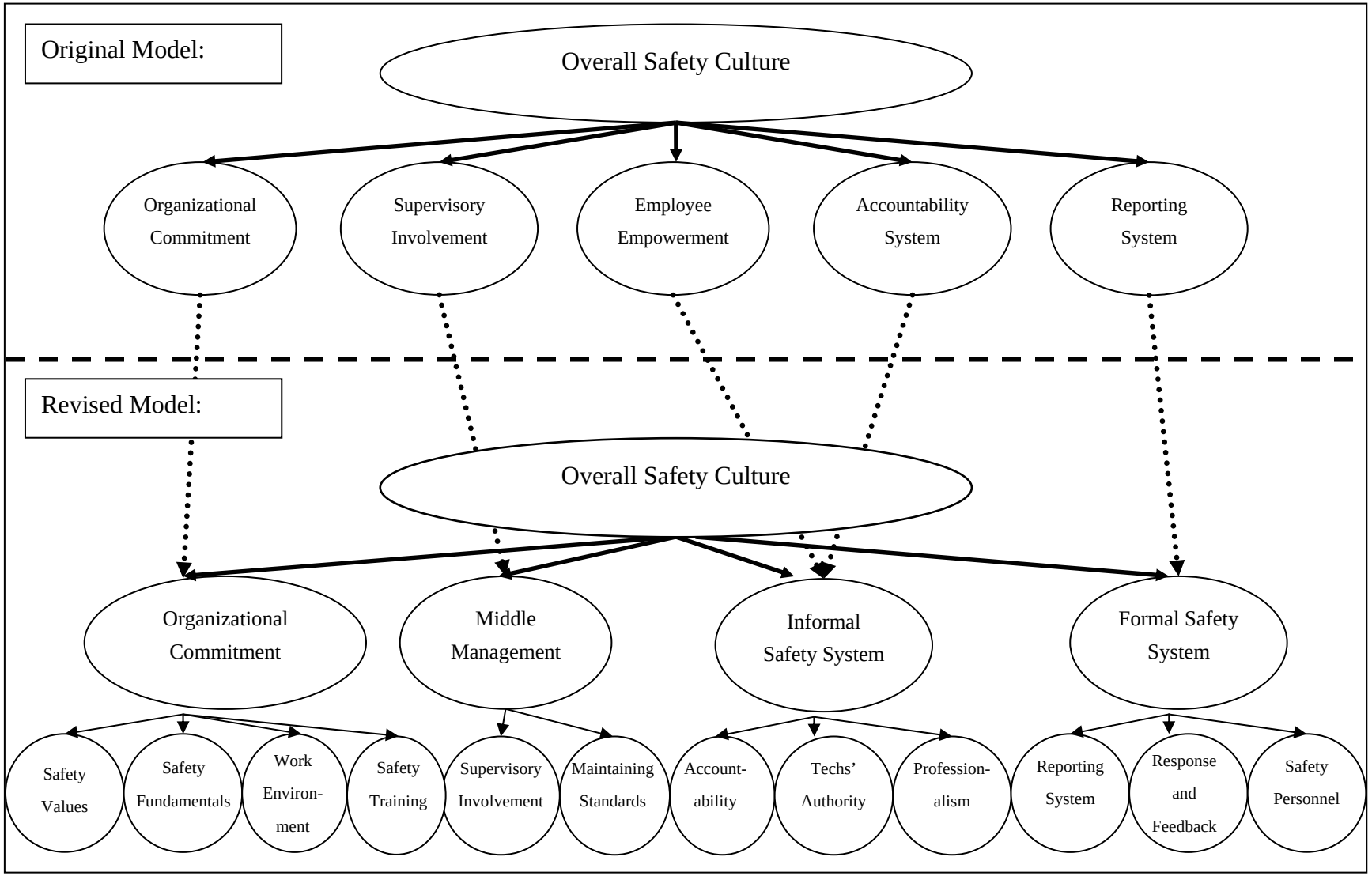


Figure 3. Revised model for maintenance survey.



The informal safety system and reporting system factors from the revised flight operations survey were retained for the revised maintenance version. For the organizational commitment factor, the safety values and safety fundamentals subfactors from the flight operations survey were kept, but a subfactor for "work environment" reflecting adequate resources for safe work, such as lighting and equipment, and a subfactor for safety training were added. The "going beyond compliance" factor was not included in the maintenance version. The supervisory involvement factor was retitled "Supervisors" and contained only two subfactors: a supervisory involvement subfactor and a "maintaining standards" subfactor. This latter subfactor referred to supervisors' consistent enforcement of high safety standards. This reorganization required the creation of several new, specific items to ensure that each subfactor had enough items to be stable in future analyses. To avoid extending the length of the survey (and thereby discouraging potential participants from responding), several items were also excluded if they seemed less relevant than or redundant with other items in the same scale. We also revised item wording wherever it appeared that an item might have been ambiguous or confusing. The revised items appear in Table 12.

Table 12. Items in final revised maintenance survey based on revised model.

Formal Safety System
Reporting System
Technicians don't bother reporting mishaps or close calls since these events don't cause any real damage.
The safety reporting system is convenient and easy to use.
Technicians can report safety discrepancies without the fear of negative repercussions.
Technicians are willing to report information regarding the marginal performance or unsafe actions of other technicians.
When technicians report a safety problem, supervisors act quickly to correct the safety issues.
Technicians are willing to file reports about unsafe situations, even if the situation was caused by their own actions.
Technicians who raise safety concerns are seen as troublemakers.
Response & Feedback
When technicians report a safety problem, it is corrected in a timely manner.
Safety issues raised by technicians are communicated regularly to all other technicians in this airline.
Technicians are satisfied with the way this airline deals with safety reports.
My airline only keeps track of major safety problems and overlooks routine ones.
Safety Personnel
Personnel responsible for safety hold a high status in the airline.
Personnel responsible for safety have the power to make changes.
Personnel responsible for safety have a clear understanding of the risks involved in airline maintenance.
Safety personnel have little or no authority compared to operations personnel.
Safety personnel demonstrate a consistent commitment to safety.
Informal Safety System

Accountability

Management shows favoritism to certain technicians.
When an accident or incident happens, management always blames the technician.
Technicians who perform substandard work are “rewarded” by receiving only the easy jobs.
The process taken to investigate possible unsafe maintenance behavior is fair.
Standards of accountability are consistently applied to all technicians.

Technicians' Authority

Technicians are actively involved in identifying and resolving safety concerns.
Supervisors support technicians who stop a job because of a concern about safety or airworthiness.
Technicians routinely perform operational checks after work is completed.
Effective communication exists up/down the chain of command.
Technicians are seldom asked for input when procedures are developed or changed.
Technicians who call in sick or fatigued are scrutinized by supervisors or other management personnel.
Technicians have little real authority to make decisions that affect the safety of normal operations.

Professionalism

Technicians view the airline’s safety record as their own and take pride in it.
Technicians who perform substandard work develop a negative reputation among other technicians.
Technicians with less seniority are willing to speak up regarding airworthiness safety issues.
Technicians never cut corners or compromise safety regardless of operational pressures to do so.
Decisions made by senior technicians are difficult to challenge.

Supervisors

Supervisory Involvement

Supervisors distribute the workload evenly among technicians.
Supervisors shield technicians from outside pressures (e.g. flight crews, dispatch).
Supervisors provide clear and helpful feedback to technicians about their safety compliance.
Supervisors keep technicians informed about potential hazards associated with maintenance activities.
Supervisors are often unhappy when technicians take time off for training.

Maintaining Standards

Supervisors do not permit technicians to cut corners.
Supervisors often fail to recognize when maintenance technicians engage in unsafe practices.
Maintenance supervisors closely monitor proficiency standards to ensure technicians are qualified to perform the assigned tasks.
Supervisors stop unsafe operations or activities.
Supervisors never pressure inspectors to sign-off on borderline work.
Supervisors are more concerned with safe maintenance than the flight schedule.

Organizational Commitment

Safety Values

Safety is identified as a “core value” in my company.
My company is more concerned with making money than being safe.
People in my company would rather cancel a flight than take a chance with whether or not

maintenance has been performed safely.
Management views regulatory violations very seriously, even when they don't result in any apparent damage.

Work Environment
Management is committed to updating tools and equipment used in aircraft maintenance (e.g. NDT equipment, diagnostic tools).
My company ensures that tools and equipment (e.g. work stands, hydraulic power sources, electrical equipment) are regularly inspected, serviced, and are safe to use.
My company ensures that the environment (e.g. lighting, air conditioning, ventilation) is conducive to effective maintenance work.
My company closely monitors tool control, calibration, and equipment certification.

Safety Fundamentals
Shift work and day-off scheduling policies at my company greatly contribute to stress and fatigue in technicians.
My company has effective shift turn-over procedures.
My company's maintenance manual and information system are kept up to date.
Maintenance checklists and procedures are easy to understand and use.
"Return to service" aircraft documentation and record keeping is taken seriously at this company.

Safety Training
Maintenance technicians are given enough training to perform their work safely.
My company provides technicians with adequate safety related training (e.g. first aid, HAZMAT, fire).
Training practices at my company are centered around operational and airworthiness safety.

While this initial test of the maintenance version of the CASS did not provide solid support for the five-factor model of safety culture, it nevertheless provided useful information on which further revisions can be based. The five scales proved useful as a diagnostic tool for identifying strengths and weaknesses of two airlines' safety cultures. Detailed factor analyses indicated that the accountability system, reporting system, and supervisory involvement factors represented fairly unitary constructs, which the employee empowerment and organizational commitment factors were more complex. As this is consistent with the findings of the flight operations version of the survey, it seems likely that this reflects true complexity in the construct rather than only measurement error. When combined with respondents' substantive comments on the items, the factor analyses yielded information that was useful in creating a revised model of maintenance safety culture parallel to that created for the flight operations version. This new model formed the basis for an extensive revision to the maintenance CASS that may be tested in future research.

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