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# Assessing Cultural Drivers of Safety Resilience in a Collegiate Aviation Program

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# Assessing Cultural Drivers of Safety Resilience in a Collegiate Aviation Program

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Organizational safety resilience is a key factor in sustaining an effective safety management system (SMS) in high-reliability organizations (HROs) such as aviation. Extant research advocates for monitoring, assessing and continuously improving safety in an organization that has a fully-functional SMS. Safety resilience provides a buffer against vulnerabilities. Extant research also suggests a paucity in terms of a measurement framework for organizational safety resilience in collegiate aviation operations. A quantitative approach using Reason's safety resilience concept (Reason, 2011) is used to assess organizational safety resilience in a collegiate aviation program with an *active conformance* SMS accepted by the FAA. A sample of 516 research participants responded to an online survey instrument derived from Reason (2011). Structural Equation Model (SEM)/Path Analysis (PA) techniques are used to assess models that measure the strength of relationships between three cultural drivers (Commitment, Cognizance, Competence) of safety and safety resilience. There were strong significant relationships between these cultural drivers and safety resilience. Path analysis suggests that Commitment significantly mediates the path between Cognizance and Competence and highlights its important role in sustaining safety competencies. There were significant differences in the perceptions of safety resilience among top-level leadership, flight operations and ground operations. Flight operations and ground operations had higher mean scores on safety resilience than top-level leadership. Study provides a validated model of safety resilience that is essential for SMS improvements in collegiate aviation programs. Future studies will utilize this safety resilience model to assess other collegiate aviation programs in various phases of SMS implementation, airlines, and air traffic control operations.

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A rapidly changing technological workspace and corresponding requirements for acceptable-levels of safety in the aviation operational environment should be complemented by a proactive safety culture and organizational resilience. Safety resilience is a characteristic of an organization that has good safety procedures and practices which enable it to have greater resistance to incidents and accidents, as well as being able to cope better when they occur (Hollnagel, Paries, Woods, & Wreathall, 2011).

Proactive safety culture and safety resilience are key enablers for effective safety management systems (SMS) implementation and continuous improvement. Under normal conditions a positive safety culture is known to be reflected in proactive behavior and to serve as indirect indicator of organizational resilience (Schwarz, Wolfgang, & Gaisbachgrabner, 2016). This acceptable–level of safety requirements has necessitated a global advocacy for a shift from prescription-based safety management among aviation certificate holders to a performance based one to enhance operational flexibility and resilience (ICAO, 2013a; ICAO, 2013b).

Improving operational capabilities while ensuring a commensurate level of acceptable safety within a resilient culture is one of the key attributes of a Safety Management System (SMS). SMS is a formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk (FAA, 2015a). Collegiate aviation programs are not under regulatory mandate by the Federal Aviation Administration (FAA) to have an SMS. However, SMS is required by certificate holders such as Part 121 airlines (Electronic Code of Federal Register. Part 5, 2015). Some collegiate aviation programs have adopted the voluntary SMS initiative promoted by the FAA due to the immense benefit derived in terms of proactive risk management and building of a resilient safety culture in their operations (Adjekum, 2014).

Despite strenuous efforts to ensure an acceptable-level of safety in operations, there are still un-anticipated safety risk in high reliability organizations (HROs) which are hazardous organizations that operate almost error-free over long periods of time (Roberts, 1990). HROs are entities that efficiently perceive changes in its environment and responds appropriately to them and where accidents can be prevented through good organizational design and management (La Porte, 1996; Weick & Sutcliffe, 2007). Examples of HROs are nuclear industry, oil and gas industry and aviation. Programs that provide aviation training at the collegiate level can be classified under generic aviation HROs. With the challenges of controlling these un-anticipated safety risks, HROs should make every effort to build a safety resilient culture to sustain a proactive safety system and prevent undesired safety events from re-occurring (Hollnagel, Woods & Leveson, 2006).

Safety resilience ensures that HRO's that operate in high risk environment such as aviation training have robust safety defenses and controls to minimize their vulnerability to adverse safety events. The topic of safety resilience within the aviation operational environment has been researched in extant literature (Akselsson, Koorneef, Stewart & Ward, 2009; Heese, 2012; Hollnagel, 2009; Hollnagel, 2014; Reason, 2011). The findings of these studies advocate for robust and resilient safety systems as the next level in an organizational that has a fully functional SMS program in place.

Reason (2011) provides a conceptual model of a safety resilience engine that drives an organization's safety program within a cultural context. Reason hypothesizes that these safety cultural drivers (3Cs - commitment, competence and cognizance) are related to resilience in an SMS program. An SMS that has reached the highest level of functionality and has all the various components established, validated and effective needs to be continuously monitored and improved due to changes in the operational environment (Schwarz & Kallus, 2015; Adjekum, 2017). Under the voluntary SMS program adopted by some collegiate aviation programs in the U.S., the level of a*ctive conformance* is attained when the Federal Aviation Administration (FAA) acknowledges full implementation of the certificate holder's SMS. The certificate holder is expected to use organizational factors to build a strong safety resilience culture aimed at reducing vulnerabilities (FAA, 2015b).

Changes such as financial status, national policies, quality of human resources, leadership attrition and high–tempo operational activities may induce safety vulnerabilities (reductions in the margins of safety that the safety controls can tolerate) (FAA, 2015a; Adjekum, 2017). Safety resilience ensures that operational vulnerabilities due to increased activities are consistently identified and managed. In the unfortunate scenario of an adverse safety event, an organization that is resilient may still recover and operate effectively.

## Research Problem

Extant studies on safety resilience in aviation have been mostly limited to commercial aviation operations and air-traffic control management (Akselsson et al., 2009; Heese, 2012; Hollnagel, 2009; Hollnagel, 2014; Reason, 2011). Specific studies on safety resilience in general aviation such as collegiate flight training seems limited if not completely missing in the United States. A search in extant literature suggests paucity in studies that assess the relationships between the cultural drivers of safety (3Cs) and organizational safety resilience in a collegiate aviation program with an *active conformance* SMS in the United States.

## Research Objectives

Studies identifying areas of safety weaknesses and improvements in SMS of collegiate aviation programs have been highly recommended (Adjekum, 2017). Determining the levels of organizational safety resilience in an SMS accepted by the Federal Aviation Administration (FAA) as being in the *active conformance* status can be beneficial to a collegiate aviation program. This study aimed at determining survey instrument items that loaded strongly on cultural drivers of safety using Confirmatory Factor Analysis (CFA). Measurement models that links these cultural drivers of safety and their underlying measured items were assessed for goodness-of-fit.

Another objective was to assess the strength of relationships between the cultural drivers of safety and organizational safety resilience in a collegiate aviation program using Structural Equation Model (SEM) techniques. A full structural model that showed the relationships between the 3Cs and organizational safety resilience was proposed. Reason (2011) suggested that there were also intrinsic relationships among the 3Cs. Mediation/ Path analysis (PA) was used to explore these relationships. Finally, variations in perceptions of organizational safety resilience in the collegiate aviation program among demographic variables such as age, functional groups and gender were analyzed.

## Research Questions

1. What is the effectiveness of measurement models of Reason's cultural drivers of safety resilience "Commitment, Cognizance and Competence" in a collegiate aviation program with an *active conformance* SMS?
2. What is the strength of relationships between the variables Commitment, Cognizance and Competence and the latent construct organizational safety resilience in a collegiate aviation program with an *active conformance* SMS?
3. What is the strength of relationships between variables Cognizance and Competence when mediated by Commitment in a collegiate aviation with *active conformance* SMS program?
4. What is the variation in perceptions among demographic variables Age, Functional Groups and Gender on the three cultural drivers of safety in a collegiate aviation program with an *active conformance* SMS?

## Literature Review

Vulnerabilities in safety defenses of any organization can precipitate errors and failures which can have adverse effects on the functional capabilities of such organizations. These vulnerabilities can cause tragic accidents, destroy value, waste resources, and damage reputations (Coombs, 2007; Yu, Sengul & Lester, 2008). Many organizations systematically strive to avoid failure, particularly when the consequences are severe, and some HRO's are able to achieve remarkably error-free operations even in the face of challenging conditions (Weick & Sutcliffe, 2007).

Extant research in safety science suggests that accident rates in "ultra-safe" systems (such as commercial aviation and nuclear power) seem to be asymptotic at around five disastrous accidents per $10^{-7}$ safety units of the system (Amalberti, 2001). These findings suggest that even for safety-conscious and safety-critical organizations, there may be challenges to eliminate all failures. This supports the assertions that accidents are inevitable in complex, tightly coupled systems (Leveson, Dulac, Marais & Carroll, 2009; Perrow, 1984). That is why the interlink between safety resilience and safety management becomes very relevant to be able to proactively identify vulnerabilities and veritable management practices that shapes the cultural drivers of safety in such organizations (Reason, 2011).

Reason (2011) posits that the engine that drives any safety initiative in an organization is primed by the cultural core of an organization. Within the core are three driving forces namely; commitment, competence and cognizance. Commitment has two components: motivation and resources. Motivation hinges on whether an organization strives to be a domain model for good safety practices, or whether it is content merely to keep one step ahead of regulatory sanctions. Resources on the other hand deals with the financial and human capital (caliber and status of those people assigned to direct the management of system safety) in the organization.

A highly resilient safety program in an organization requires the technical competence necessary to achieve enhanced safety. Paries, Valot and Deharvenght (2018) using a generic taxonomy of safety management modes, within the French Air Navigation Service Provider (ANSP), found out that formal SMS implementation did not include many of the HROs features. However, the researchers also found out that in the real “life” of the organization, particularly at operational levels (control rooms and maintenance units), most of the HROs features could be observed as informal work or skills. Paries et al. (2018) further suggests some defining technical competencies of HROs as follows:

a. Identification of hazards and safety-critical activities.
b. Preparations and contingencies for crises and linking of crisis plans closely to business-recovery plans.
c. Ensuring the defenses, barriers and safeguards possess adequate diversity and redundancy.
d. Creating a structure of the organization that is sufficiently flexible and adaptive.
e. Ensuring the right kind of safety-related information is being collected and analyzed appropriately.
f. Getting this information disseminated and making sure it is acted upon.

Cognizance is the final driver within the cultural core that determines the need for an organization to be adequately conscious of the dangers that threaten its activities and understand the true nature of the struggle for enhanced resilience. An organization must always be in state of intelligent wariness even in the absence of bad outcomes (Reason, 2011; Hollnagel, 2014). This is the very essence of a proactive safety culture. Cognizance ensures that the primary goal of safety management which is, maintaining a region of the safety space associated with the maximally attainable level of intrinsic resistance, is achieved (ICAO, 2013a).

In their research on resilience within the healthcare industry, Smith and Plunkett (2019) posits a link between cognizance and competence. Their study analyzes the distinction between ‘work as imagined’ and ‘work as done’ as originally suggested by Hollnagel (2009). ‘Work as imagined’ assumes that if the correct standard procedures are known, understood and followed, safety will follow as a matter of course. However, staff at the ‘sharp end’ of organizations know that to create safety in their work, variability is not only desirable but essential. This positive adaptability within systems that allows good outcomes in the presence of both favorable and adverse conditions is termed resilience. They further argue that clinical and organizational work can be made safer, not only by addressing negative outcomes, but also by fostering excellence and promoting resilience through non-punitive safety reporting.

Even within industries where there are formally established safety practices such as aviation and the offshore oil industry; practical skills, support from colleagues, the creation of ‘performance spaces’ and flexibility in problem-solving (all rooted in the informal elements of work) are important in maintaining safety (Hollnagel, 2009). Oliver, Calvard, and Potočnik

(2017) in a study on cognition, technology, and organizational limits suggest that HRO's may hold important lessons for other organizations as they tread a path between developing capabilities for safety resilience aimed at avoiding errors and subsequent failures.

They also suggest that controllers of complex systems, whether they are pilots or executives, run the risk of becoming insulated from the systems that they oversee. For top-level management executives, this might result in separation from front-line operations, such as when responsibilities are delegated to units who largely follow established protocols, resulting in organizational mindlessness (Sutcliffe, Vogus & Dane, 2016). This is where commitment needs to mediate the relationship between cognizance and competence at all levels.

Oliver et al. (2017) further found out that vulnerabilities in highly complex systems are sometimes not matched by the organization's ability to organize and control them in the face of most conceivable conditions, let alone unpredictable ones. As organizations and systems grow in scale and complexity, the issue of how to develop an organization to handle unexpected and extreme events grows ever more challenging.

The implication is that top-management executives should continuously monitor and develop improvement strategies to respond appropriately to unusual conditions. The cultural drivers, namely; competence by top-level management and cognizance at all levels within the organization is paramount for ensuring the organizational safety goal of resilience. Finally, the assessment of the strength of relationships among the cultural drivers of safety is suggested by Reason (2011) as the SMS becomes fully-functional and there is a constant shift in safety space between vulnerabilities and resilience.

## Methodology

### Research Design

A quantitative research design involving an online and anonymous survey was used to elicit the perceptions of respondent on scale items related to safety resilience in a collegiate aviation program. Likert scaled items (1= strongly disagree to 5 = strongly agree) were adapted from Reason's attributes of a proactive safety resilient organization (Reason, 2011) and a face /content validity review was done by two SMS subject -matter experts (SME) with combined working experience of almost 40 years as SMS training facilitators, researchers and collegiate aviation faculty members. Based on recommendations from the review, some minor changes in survey items sequencing were done.

The cultural driver *Commitment* has 9 items with "Personnel proactively discuss safety-related issues whenever the need arises" being an example of construct item. *Competence* has 7 items and an example of construct item is "There are standard operating procedures for recovery from errors recognized which are reinforced by training." The third cultural driver *Cognizance* has 7 items and an example of construct item is "There are comparable procedures in place to ensure safe transitions from the normal to emergency status." Details of survey items used for analysis is shown in Appendix A. A sample size greater than 300 was recommended as expedient to obtain meaningful fit of the measurement models based on Kline (2005) SEM recommendations using model parameters.

### Sampling and Survey Dissemination

A population of about 1850 comprised of students, faculty and supporting staff of a collegiate aviation program in a large university located in the North-Western part of the U.S. was sampled in this study. A convenience sampling approach was used to send an anonymous online survey link via email to participants (aviation students, certified flight instructors, faculty, maintenance, dispatch and top-level management) in the aviation program that also has an *active conformance* level SMS accepted by the FAA.

The introduction of the survey had the research purpose, objectives and contact information about the researchers. It also had a digital consent which provided the option to accept or decline participation. For those who consented to participate, a hyperlink was provided on completion of survey directing them to another site where participants could submit their emails to win a $20 gift card in a random draw. The online survey was open for a three-week period in the Fall semester of September 2019.

### Data Collection and Preliminary Data Analysis

Relevant demographic data to assist in understanding the population was collected and highlighted in this paper and will also be used in another study aimed solely at demographic variations on safety resilience. At the end of the survey response period, the data was transferred from the Qualtrics® survey site into IBM SPSS® version 26 software for preliminary screening. The data was screened for multivariate normality using a combination of visual means such as normality plots of histogram, kurtosis/skewness values and N-N plots (Fields, 2018). There were no severe indications of non-normality or outliers in data that warranted transformations. IBM SPSS® 26 analysis function for "pair-wise deletion of missing data" was used for the missing data analysis. The full-information maximum likelihood approach using the IBM AMOS® V25 was used for model assessments, strength of relationships between measurement scale variables (items), and the cultural drivers of safety (Enders & Bandalos, 2001).

### Instrument Reliability, Construct Validity, and Goodness-Of- Fit Indices Criteria

The reliability of scale items underlying factors representing the cultural drivers that generated acceptable fit for CFA models was determined. The outcomes from CFA models were used to assess the reliability, convergent validity, and discriminant validity. A Cronbach's alpha ($\alpha$) value of 0.7 or higher indicates good reliability of measured items (Nunnally, 1978) and SPSS 26 was used to determine the reliability. Commitment ($\alpha$ = .85 for 7 items) and Competence ($\alpha$ = .80 for 6 items) had good reliability. The factor Cognizance had a fair reliability after the first analysis ($\alpha$ =. 54 for 5 items) and the reliability improvement function of SPSS was used to delete the items cog 6 and cog 7. The next iteration improved the reliability ($\alpha$ = .70 for 3 items) to an acceptable level.

The average variance extracted (AVE) method was used to assess the convergent validity (Fornell and Larcker, 1981). The AVE for commitment (.43), cognizance (.42) and competence (.42) were all below the criteria suggested by Fornell and Larcker (AVE > .50). This result suggests weak evidence of convergent validity. Using the Chin (2010) and Henseler & Sarstedt (2015) recommendations of checking for cross-loading in the correlation matrix, some evidence of discriminant validity also called "item-level discriminant validity" was observed. The correlation matrix did not show any form of cross-loading of items among the constructs.

According to Gefen and Straub (2005), an item should be highly correlated with its own construct, but have low correlations with other constructs in order to establish discriminant validity at the item level. Hair, Ringle & Sarstedt (2011) recommends that the cut-off values of factor loadings should be higher than .70.in that case. The evidence of weak convergence validity should be taken into consideration when interpreting the results despite the evidence of discriminant validity.

The items in each factor were summed up and used as indicator variables to assess the relationship between cultural drivers and the over-arching concept of safety resilience. A model containing all the individual measurement models was assessed for fit. Finally, the strength of relationships and levels of interaction among the three cultural drivers were also assessed using causal path analysis and Hayes Process V.3.4 in SPSS (Fields, 2018). A full structural model showing relationships between cultural drivers of safety and safety resilience was proposed. Annex A has all the measurement items retained after the reliability and validity assessment. Annex B has details of correlation matrix highlighting lack of cross-loading among construct items.

A large class of omnibus tests exists for assessing how well measurement models matches observed data. The chi-squared ($\chi^2$) is a classic goodness-of-fit measure to determine overall model fit. However, the chi-squared is sensitive to sample size, and it becomes difficult to retain the null hypothesis as the number of cases increases (Kline, 2005). The $\chi^2$ test may also be invalid when distributional assumptions are violated, leading to the rejection of good models or the retention of bad ones (Steven, 2002; Brown, 2006; 2015).

Another commonly reported statistic is the Root Mean Square Error of Approximation (RMSEA). A recommended value of 0.05 or less indicates a close fit of the model in relation to the degrees of freedom (Brown, 2006; 2015). Another test statistic is the Comparative Fit Index (CFI) that evaluates the fit of a user-specified solution in relation to a more restricted, nested baseline model, in which the covariance among all input indicators are fixed to zero or no relationship among variables is posited (Brown, 2006).

The fit index CFI ranges from 0, for a poor fit, to 1 for a good fit. Finally, the Tucker-Lewis Index (TLI) is another index for comparative fit that "includes a penalty function for adding freely estimated parameters" (Brown, 2006, p. 85). Other indices are the Normed Fit Index (NFI) and Incremental Fit Index (IFI). Hu and Bentler (1999) provided rules of thumb for deciding which statistics to report and choosing cut-off values for declaring significance. When RMSEA values are .06 or below, and CFI and TLI are .95 or greater, the model may have a reasonably good fit. In this study, the TLI, $\chi 2$, RMSEA, CFI, NFI and IFI were reported for measurement models. If the model fit was not satisfactory, a post hoc analysis was performed to modify the CFA model to make it better fit. Items with high error covariance were eliminated as necessary.

## Results and Findings

There were 519 responses at the end of the survey period. Out of the 519 responses, 516 respondents consented to undertake the survey (99.42%) and 3 declined (0.58%). Details are outlined in Table 1. Out of the 516 positive responses, only 481 respondents provided details about their functional personnel group. The details of the demography are outlined in Table 2.

Table 1
*Consent to Participate in Anonymous Survey*

| Answer | Percentages (%) | Count |
|---|---|---|
| Yes | 99.42% | 516 |
| No | 0.58% | 3 |
| Total | 100% | 519 |

Table 2
*Functional Group of Respondents*

| Functional Groups | Percentages (%) | Count |
|---|---|---|
| Flight Operations (Aviation Students & Flight Instructors) | 76.50% | 368 |
| Top-level Management/Faculty (Administrative) | 9.56% | 46 |
| Operations Support Staff (Maintenance/Dispatch/Ground) | 13.94% | 67 |
| Total | 100% | 481 |

There were 420 responses to this item on the survey and the demographic layout suggest that majority of the student respondents to this item were juniors (29.05%). The breakdown of responses, counts and percentages are outlined in Table 3.

Table 3
*Student Academic Group*

| Answer | Percentages (%) | Count |
|---|---|---|
| Freshman | 15.00% | 63 |
| Sophomore | 27.62% | 116 |
| Junior | 29.05% | 122 |
| Senior | 23.81% | 100 |
| Graduate | 4.52% | 19 |
| Total | 100% | 420 |

Respondents were asked to provide details about their highest flight certification and ratings and the result suggest that majority of respondents were private pilot certificate holders (46.90%). Among the other responses were participants with Airline Transport Pilot (ATP) certification (7), Airframe & Power Plant (A&P) ratings (5), 1 respondent with Airframe and Power Plant with Inspection Authorization (A&P IA) and 10 non-pilots. Figure 1 outlines details of the demographic lay out.

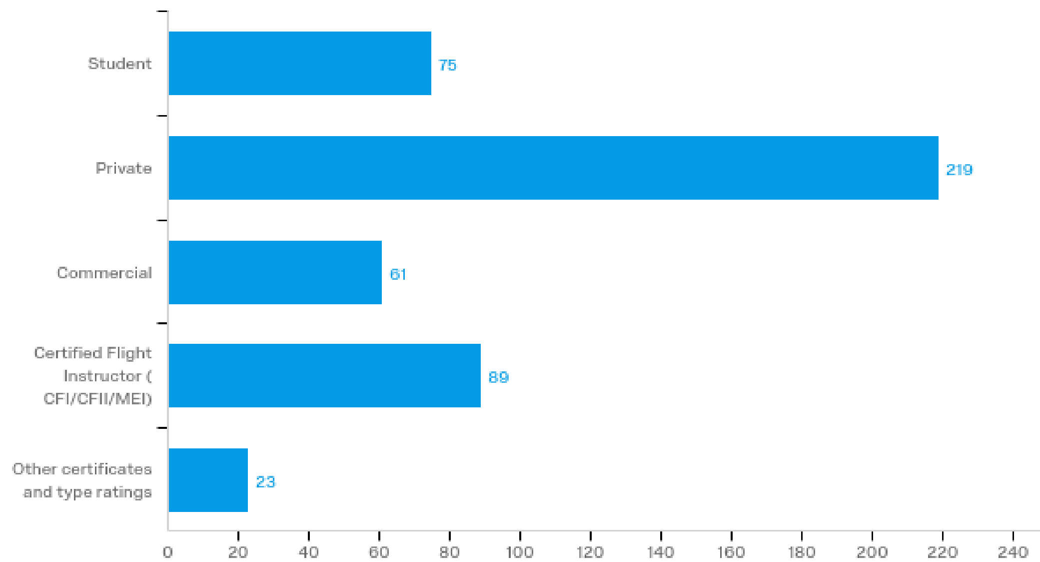



*Figure 1*. Highest Flight Certificate/Ratings Held

## Age and Gender

Respondents were asked to provide their age as part of this study. There were 470 responses and results show a mean value close to 23 years (M =22.94, SD = 7.944) with a median of 20 years. Result also showed that the modal class was the 20-year old respondents and the highest age was 67 years. There were 396 male respondents (76.7%) as compared to 120 female respondents (23.3%). Table 4 shows the descriptive statistics for *Age* variable.

Table 4
*Age distribution of Participants*

| Item | Value |
|---|---|
| Mean | 22.94 |
| Median | 20.00 |
| Mode | 20.00 |
| Std. Dev. | 7.944 |

*Question One*
*What is the effectiveness of measurement models of Reason's cultural drivers of safety resilience "Commitment, Cognizance and Competence" in a collegiate aviation program with an active conformance SMS?*

A first-order CFA was conducted to evaluate the strength of relationships between a set of seven measurement items and the latent construct cognizance. A measurement model is normally used to examine the relationships between the observed variables and the latent factors. CFA allows researchers to test hypotheses about a factor structure (e.g., factor loading between the first factor and first observed variable). Unlike an Exploratory Factor Analysis (EFA), a CFA is theory-driven and produces several goodness-of-fit measures to evaluate the model. However, it does not calculate factor scores (Brown, 2006; 2015).

A five-item measurement model with good fit indices for cognizance was obtained after the initial seven-item model did not yield a good fit. A post-hoc modification using the Modification Indices (MI) function in AMOS recommended the addition of a covariance to the error terms of items cog6 and cog7. The items cog 4 and cog5 were deleted due to extremely low loadings and their adverse effect on fit indices. The final measurement model had good fit; $\chi^2$ (4, $N$= 516) = 7.991, CMIN/DF = 1.998, $p$ = .092, NFI = .971, IFI = .985, TLI =.943, CFI = .983, RMSEA = .044 (.000 - .088). Figure 2 shows the measurement model and Table 5 shows details of the factor loadings and squared multiple correlations (SMC or $R^2$). All β are significant to .000 level.

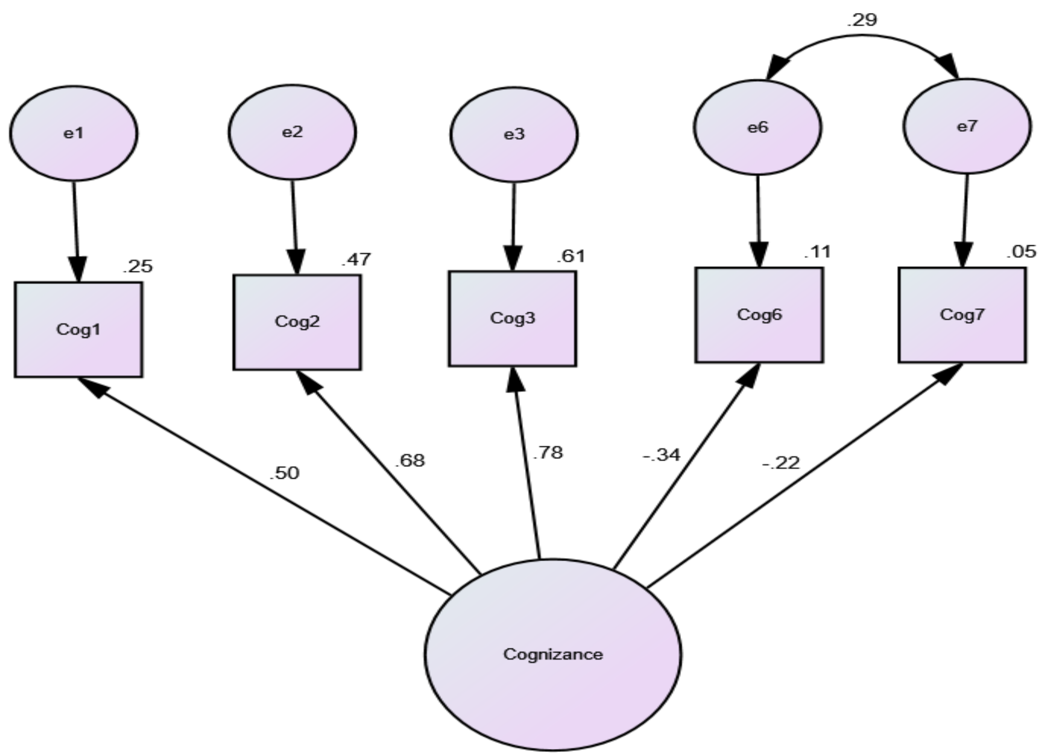



*Figure 2*. Measurement model of Cognizance

Table 5
*Standardized Regression Weight and Squared Multiple Correlation of Cognizance*

| Measurement Item | (β) | $R^2$ |
|---|---|---|
| Cog 1 | .504 | .252 |
| Cog 2 | .683 | .466 |
| Cog 3 | .781 | .610 |
| Cog 6 | -.336 | .113 |
| Cog 7 | -.220 | .048 |

Note: All beta values are significant to p < .001 level

A final seven-item model with the best fit indices was obtained for the factor Commitment after various competing models were assessed and post-hoc iterations were done using MI and Reason's theoretical framework. Figure 3 shows the measurement model and Table

6 shows details of the factor loadings and squared multiple correlations (SMC or $R^2$). Details of the competing models are outlined in Table 7.

Table 6
*Standardized Regression Weight and Squared Multiple Correlation of Commitment*

| Measurement Item | (β) | $R^2$ |
|---|---|---|
| Comm 1 | .695 | .483 |
| Comm 2 | .618 | .383 |
| Comm 3 | .701 | .500 |
| Comm 4 | .644 | .415 |
| Comm 5 | .736 | .541 |
| Comm 6 | .561 | .315 |
| Comm 7 | .622 | .387 |

Note: All β are significant to p< .001 level

Table 7
*Goodness-of -Fit Indices for Commitment*

| Iteration | Chi Square ($X^2$) | NFI | IFI | TLI | CFI | RMSEA |
|---|---|---|---|---|---|---|
| Model 1 | $\chi^2$ (0, *N*= 516) = not computed, CMIN/DF = not computed, *p* = not computed | .929 | .944 | .887 | .943 | .080 (.060 -.10) |
| Model II | $\chi^2$ (13, *N*= 516) = 51.520, CMIN/DF =3.963, $p < .001$ (Covary e6/e7) | .939 | .954 | .898 | .953 | .076 (.055 -.098) |
| Model III | $\chi^2$ (12, *N*= 516) = 40.832, CMIN/DF = 3.403, $p <.001$ (Covary e6/e7; e1/e2) | .952 | .965 | .918 | .965 | .068 (.046 -.092) |
| Model IV | $\chi^2$ (11, *N*= 516) = 40.832, CMIN/DF = 1.937, $p =.030$ (Covary e1/e2; e4/e5; e6/e7) | .975 | .988 | .968 | .987 | .043 (.013 -.069) |

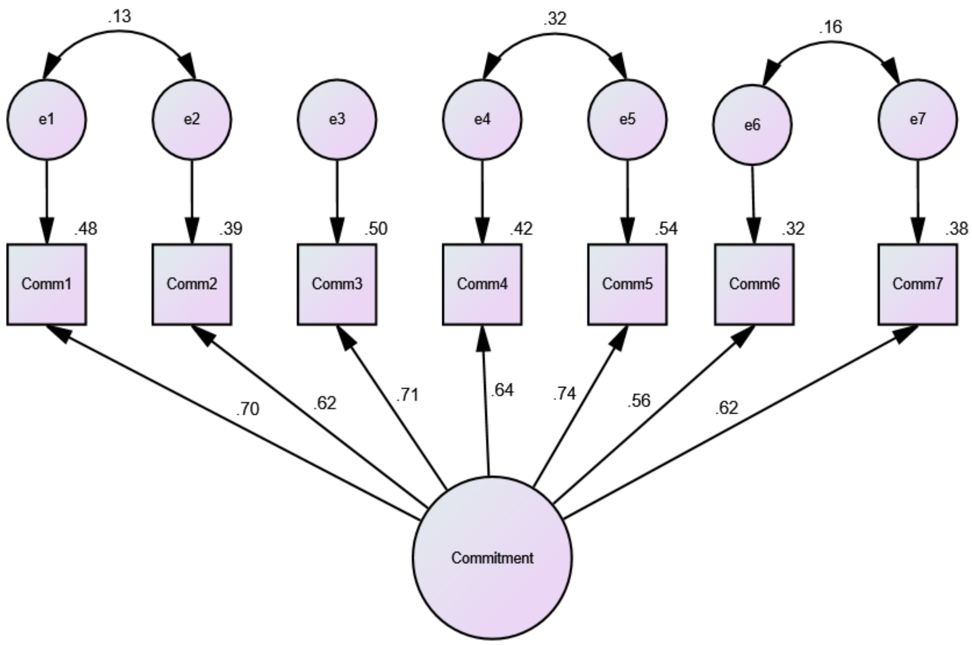



*Figure 3*. Measurement Model for Commitment

A final six-item model with good fit indices; $\chi^2$ (9, *N*= 516) = 8.849, CMIN/DF = .983, *p* = .451, NFI = .983, IFI = .995, TLI =.997, CFI = .998, RMSEA = .001 (.000 - .049) was obtained for the factor Competence. There was no need for any post-hoc iterations using MI and Reason's theoretical framework. Figure 4 and Table 8 shows the measurement model and values of β and $R^2$ respectively.

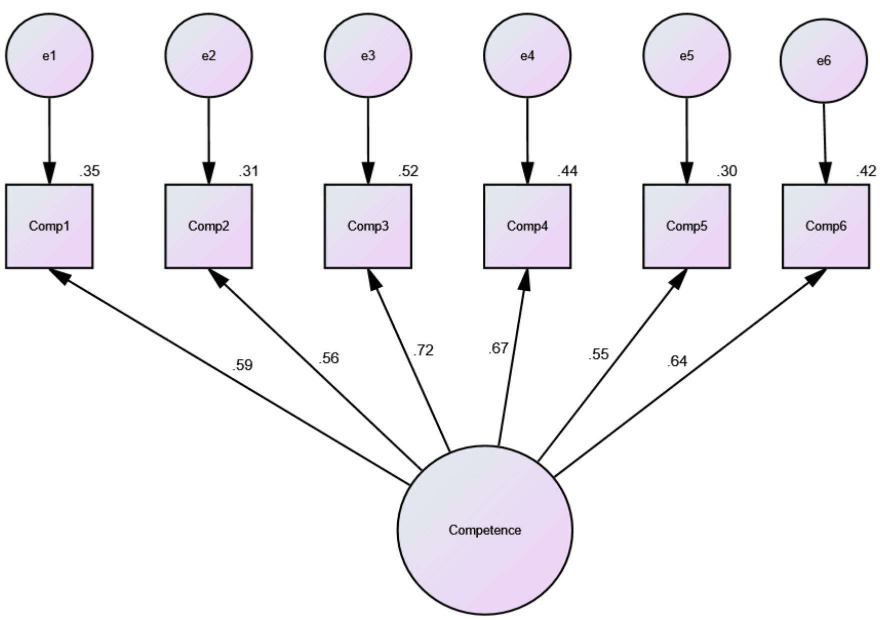



*Figure 4*. Measurement Model for Competence

Table 8
*Standardized Regression Weight and Squared Multiple Correlation of Competence*

| Measurement Item | (β) | $R^2$ |
|---|---|---|
| Comp 1 | .591 | .350 |
| Comp 2 | .555 | .308 |
| Comp 3 | .724 | .524 |
| Comp 4 | .665 | .448 |
| Comp 5 | .548 | .300 |
| Comp 6 | .644 | .415 |

Note: All β are significant to $p < .001$ level

*Question Two*
*What is the strength of relationships between the variables Commitment, Cognizance and Competence and the latent construct organizational safety resilience in a collegiate aviation program with an active conformance SMS?*

Scale items underlying each cultural driver of safety with good reliability and validity were summed up to produce measured variables. The strength of relationships between these measured variables (commitment, competence, cognizance) and latent construct safety resilience were assessed using SEM/PA. The result suggests a significant predictive relationship between measured variables and the latent construct safety resilience. A full structural model that establishes the relationships between the cultural drivers of safety and the over-arching construct safety resilience had an acceptable fit; $\chi^2$ (98, $N$= 516) = 375.877, CMIN/DF = 3.240, $p$ = .000, NFI = .840, IFI = .893, TLI =.841, CFI = .881, RMSEA = .059 (.050 - .073). Figure 5 shows the full structural model.

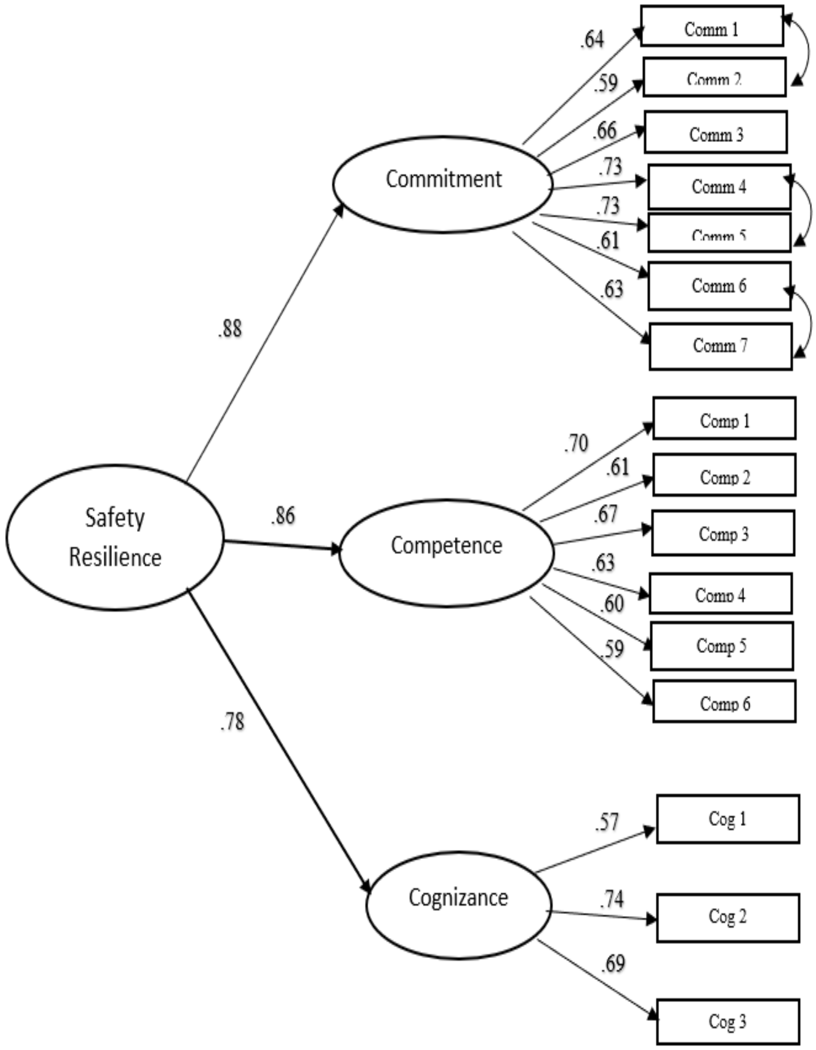



*Figure 5*. Final Structural Model of Relationships between 3Cs and Safety Resilience

The results from Figure 5 show that commitment and competence had the highest standardized regression weight of .88 and .86 respectively. Cognizance had the lowest standardized regression weight of .78. All of these were significant at p = .000. The SMC values and the standardized regression weight for all three cultural drivers are shown in Table 9. The results suggest that when safety resilience goes up by 1 standard deviation, there is a corresponding increase of .88 standard deviation in commitment. A unit standard deviation increase in safety resilience produces a corresponding .86 standard deviation in competence and .78 standard deviation in cognizance respectively. The $R^2$ value of commitment suggests that about 77% of the variances in commitment can be explained by predictors in the measurement model of commitment.

Table 9
Standardized Regression Weight and Squared Multiple Correlation of Safety Resilience

| Factor | (β) | $R^2$ |
|---|---|---|
| Commitment | .876 | .767 |
| Competence | .862 | .743 |
| Cognizance | .789 | .623 |

Note: All β are significant to p< .001 level

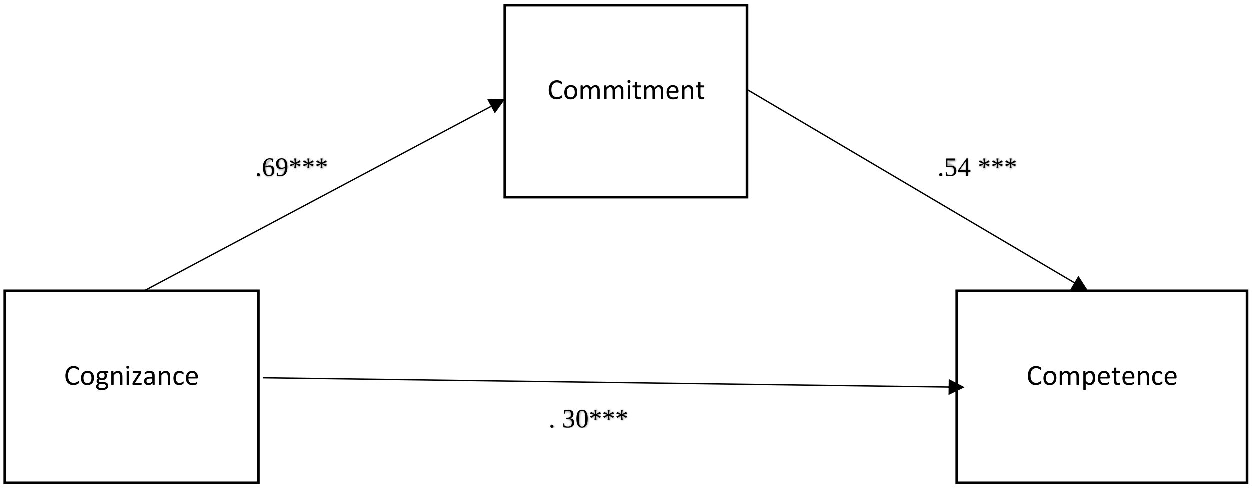
*Question Three*
*What is the strength of relationship between variables Cognizance and Competence when mediated by Commitment in a collegiate aviation with active conformance SMS program?*

The PROCESS Version 3.4 for SPSS 26 (Fields, 2018) with bootstrap corrected accelerated (BCa) value of 5000 was used for a mediation analysis to assess the strength of relationships when commitment serves as a mediating variable between cognizance and competence. This analysis was based on Reason's suggestion that there exist intrinsic relationships among the 3Cs. It also aimed at exploring the potential mediating role of commitment in the relationship between cognizance (awareness) and competence of personnel in a collegiate aviation SMS environment.

The exogenous variable was cognizance and the endogenous variables were commitment and competence. The first model suggests a significant direct path between cognizance [β = .69, t (334) = 17.43, $p$ = .000, 95% BCa (.559 - .701)] and competence. The model summary was [ $F$ (1, 334) = 303.64, $p$ < .001, $R^2$ = .48] and shows about 48% of the variances of commitment is explained by cognizance.

The path between cognizance [β = .31, t (333) = 6.58, $p$ = .000, 95% BCa (.211 - .392)] and competence was significant. The path between commitment [β = .54, t (333) =11.62, $p$ = .000, 95% BCa (.485 - .823)] and competence was also statistically significant. The model summary [$F$ (2, 333) = 270.78, $p$ < .001, $R^2$ = .62] shows about 62% of the variances in competence can be explained by cognizance and commitment.

The standardized indirect effect of cognizance on competence was 0.375. Due to the indirect (mediated) effects of commitment on competence, when cognizance goes up by 1, competence goes up by about 0.38. The standardized indirect effect of cognizance on competence was higher than the standardized direct effect of cognizance on competence (.302) and validates the significant mediating role of commitment in the relationship. Figure 6 shows the causal path of the variables.




Note: all regression weights are significant; p < .001

*Figure 6*. Causal Path Diagram of Cultural Drivers of Safety Interactions

*Question Four*
*What is the variation in perceptions among demographic variables Academic Levels, Functional groups and Gender on the three cultural drivers of safety in a collegiate aviation program with an active conformance SMS?*

A one-way Analysis of Variance (ANOVA) was conducted to determine if there existed significant differences in the perceptions on dependent variables (3C) among demographic variables academic levels, functional groups and gender. Only the functional group means yielded significance and post-hoc analysis was conducted. The results show that there were differences in the perceptions on commitment between the top-level management (M= 3.95, SE =.487) and flight operations (M = 4.76, SE = .308).

In terms of cognizance there was a significant difference between the perceptions of top-level management (M= 3.88, SE =.542) and flight operations (M = 4.74, SE = .339). There also existed a significant difference in the perceptions of the top-level management (M= 3.89, SE =.514) and operations support (M = 4.71, SE = .033) found in the cultural driver competence. An independent *t*-test was conducted to find out if there existed any significant differences in the mean of perceptions per gender. Result suggests no significant differences. Table 10 shows the results of the ANOVA for all three factors.

Table 10
*ANOVA for Functional Groups*

| Factors | df1/df2 | *F* | Sig. |
|---|---|---|---|
| Commitment | 2, 336 | 3.840 | .002 |
| Cognizance | 2, 349 | 3.155 | .008 |
| Competence | 2, 336 | 4.452 | .001 |

Note: p < .05 (2-tail)

## Discussion and Conclusions

A structural model that assesses the strength of relationship between the cultural drivers of safety and the overall construct of safety resilience showed a good fit to the data. The results suggest that all the 3 cultural drivers have significant predictive relationship with safety resilience with almost 88% of the proportion of variances in commitment explained by safety resilience. About 86% of the variances in competence can be accounted for by safety resilience and about 78 % of the variances in cognizance accounted for by safety resilience. The results validate Reason (2011) concept of safety resilience and its relationship with cultural drivers of safety. The findings of this study corroborate Hollnagel (2014) and Akselsson et al. (2009) suggestions that safety resilience is an important element in the continuous monitoring and improvements of SMS in aviation.

Results also suggest that it is very important for collegiate aviation programs to constantly ensure that the mechanisms underlying resilience are assessed and improved. Cultural drivers such as competence, cognizance and commitment should have metrics that needs to be reviewed periodically during safety audits and SMS assessments to identify gaps and misalignments with desired outcomes. Competence requires effective training and mentoring and that leads to building the capacity of all personnel in the organization to be prepared and have contingencies for situations that has adverse impact on organizational missions and goals as posited by Adjekum (2017) and Stolzer & Goglia (2015).

The fact that cultural driver commitment significantly mediates the path between cognizance and competence is also intuitive. It shows that even though a robust awareness or educational program can be inherent in the SMS of a collegiate aviation, it may be inadequate as a stand-alone to ensure competence of personnel in safety resilience. It will require motivation from top-level management personnel, immediate supervisors and sometimes peers to enhance competence. The provision of adequate material, financial and moral support also enhances commitment to resilient practices.

Reciprocity in commitment is also required for personnel. Top-level management can provide time and money for personnel training and development to build knowledge and skills. These capacity-building resources ensures a safe working environment. Unfortunately, learning and application cannot be forced and personnel must be self-committed to learning and application of concepts to ensure competencies. Top-level management should provide empowered accountability that allows personnel to recognize hazards and the authority to mitigate the hazards. Such commitments also allow for work stoppage or deference to higher supervision when risk mitigation is above competencies.

The results show that the mean perceptions of top-level management were relatively lower for all three cultural drivers as compared to that of operations support and flight operations (aviation students and flight instructors). However, it was only the difference between the top-level management and operations support that was significant. This was quite surprising considering that in a previous study that assessed perceptual gaps in a collegiate aviation safety culture, top-level management had a better score than front-line personnel (Adjekum, 2017). The findings of the Adjekum (2017) study suggested that top-level management as resource providers, deemed their efforts at sustaining safety culture adequate which was not reflected by the perceptions of front-line personnel. In the present study, the assumption is that top-level management may be privy to resource constraints and prospective strategic initiatives that can pre-dispose aviation operations in their organization vulnerable, hence their seeming wariness as compared to front-line personnel.

An example could be un-anticipated financial disruptions and aviation industry market upheavals that can introduce vulnerabilities in aviation operations. To bridge the perceptual gaps related to the cultural drivers of safety resilience and SMS, transparency in information flow and periodic interaction between top-level management and front-line personnel is important. Overall, the perceptions on all three factors that underly safety resilience namely; commitment, cognizance and competence were good in the collegiate aviation program. It is highly recommended that periodic assessments of safety resilience are performed to make operations robust to such adversities.

### Limitations and Generalizability of Findings

The findings of this study are based on perceptions of research participants from a single collegiate aviation program. Also, majority of the respondents to the survey were collegiate flight students and instructors who have relatively lower exposure to high tempo resilient practices experienced in commercial airline or military flight operations. They may also have minimal experiences with high impact safety occurrences that require higher levels of safety resilience to ensure business continuity. Therefore, results from this study should not be generalized across the aviation industry even though it can be relevant to other collegiate aviation programs of scope and complexity.

The weak evidence of convergence validity should be taken into consideration when making inferences on the findings in this study. It is recommended that future studies re-evaluate survey items for convergent validity. The uneven sample size of the functional groups should be considered when making inferences from the results of the ANOVA analysis. The majority of the respondents were young aviation students and flight instructors (M=23 years) and their perceptions on safety resilience and risk tolerability could have be shaped by psycho-social factors such as exuberance, peer-pressure and high self-efficacy (Thomson, Önkal, Avcioğlu & Goodwin, 2004; Adjekum, 2017; Wang, Zhang, Sun & Ren, 2018).

## Implications of Study Findings for Research and Policies

This current study provides a veritable structural model with an acceptable fit and provides a framework for future studies on organizational safety resilience in aviation. These future studies recommended may include a comparative analysis of organizational safety resilience in collegiate programs with active conformance SMS status, those going through the voluntary process (active applicant and active participant) and those who are non-conformant (without an accepted SMS program).

Such a study could also provide a plethora of literature and additional assessment tools for organizational safety resilience in other certificate holders such as Airline Part 121, Air

Traffic Management, Airports and Unmanned Aerial Systems operations. Another significant benefit of this study is the capacity to assess operational vulnerabilities and strengthen safety resilience in collegiate aviation programs as part of continuous monitoring and improvements of SMS.

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# Appendix A

Details of Measurement Items used in Assessment

| Code | Measurement Item |
|---|---|
| Comm1 | The safety mission statement is continually endorsed by top leadership's allocation of required resources (human/financial/technological) |
| Comm 2 | Personnel proactively discuss safety-related issues whenever the need arises |
| Comm 3 | Safety management issues are promptly attended to by top leadership without constraints |
| Comm 4 | Procedures are in place within the organization to facilitate continuing professional development of personnel (new procedures/ techniques) |
| Comm 5 | Procedures are in place to ensure that personnel under training attain pre-established competency standards |
| Comm 6 | Trainees receive positive mentoring from instructors |
| Comm 7 | Safety is recognized as being everyone's responsibility not just that of the safety management team |
| Comp 1 | Top level leadership adopts a proactive stance towards safety |
| Comp 2 | There are agreed standards for safety behaviors (acceptable/unacceptable) |
| Comp 3 | Before any complex/unusual procedures, operational teams are briefed accordingly |
| Comp 4 | Operational teams are debriefed after a task where necessary |
| Comp 5 | Procedures backed by constant reminders helps to keep personnel knowledgeable in their job. |
| Comp 6 | Useful feedback on lessons learned from safety events are quickly put into practice by personnel |
| Cog 1 | Policies ensure that supervisory personnel are present throughout high-risk procedures. |
| Cog 2 | There are standard operating procedures for recovery from errors recognized which are reinforced by training |
| Cog 3 | There are comparable procedures in place to ensure safe transitions from the normal to emergency status (vice-versa) |
| *Cog 4R | Top leadership blame specific individuals who were involved in accident/incidents rather than improving failed system defenses |
| *Cog 5R | Personnel are not informed by feedback on recurrent error patterns in operations |

R – Item was reverse coded; * Removed from final structural model due to low reliability

## Appendix B

Cross-Loading Analysis of Correlation Matrix; Chin (2010) & Henseler et al. (2015)

| | Commitment | Cognizance | Competence |
|---|---|---|---|
| Commitment | 1 | | |
| Cognizance | .690 | 1 | |
| Competence | .756 | .678 | 1 |
| Comm1 | .710 | .408 | .453 |
| Comm 2 | .668 | .407 | .472 |
| Comm 3 | .734 | .503 | .538 |
| Comm 4 | .734 | .553 | .669 |
| Comm 5 | .715 | .478 | .532 |
| Comm 6 | .691 | .457 | .538 |
| Comm 7 | .690 | .406 | .456 |
| Comp 1 | .636 | .521 | .677 |
| Comp 2 | .550 | .461 | .659 |
| Comp 3 | .510 | .526 | .760 |
| Comp 4 | .497 | .515 | .733 |
| Comp 5 | .569 | .410 | .644 |
| Comp 6 | .468 | .400 | .745 |
| Cog 1 | .510 | .754 | .455 |
| Cog 2 | .595 | .765 | .615 |
| Cog 3 | .541 | .837 | .539 |