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Assessing the relationship between organizational management factors and a resilient safety culture in a collegiate aviation program with Safety Management Systems (SMS)

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ABSTRACT

Extant research advocates for assessing and continuously improving resilient safety culture in high-reliability organizations (HROs) such as aviation that has a fully functional Safety Management Systems (SMS). Perceptions on the relationship between four (4) organizational management factors (*Principles*, *Policy*, *Procedures*, *Practices*) and resilient safety culture in a collegiate aviation program was assessed using an online survey instrument drafted using Reason (2011) concept on safety resilience. Sample was drawn from aviation students, flight instructors, faculty and administrators. Structural Equation Model (SEM) and Causal Path Analysis (CPA) techniques were used to assess conceptual models. Results suggest good reliability and construct validity for survey instrument. All the measurement models had acceptable fit based on various goodness-of-fit indices. The results suggest all four management factors had significant predictive relationship with resilient safety culture. *Practices* had the weakest predictive relationship and *Policy* had the highest. *Procedures* strongly mediated path between *Policies* and *Practices* and there was no significant causal relationship between *Principles* and *Practices*. Results suggest that more focus should be placed on resilient safety practices in the collegiate aviation program. Significant benefit of this study is the validation of an instrument that explores the relationship between resilient safety culture and organizational management factors and adds to literature on resilient safety culture in collegiate aviation programs. Future studies using this survey instrument and models in other collegiate aviation programs, airlines and airports are highly recommended.

1. Introduction

A rapidly changing technological workspace and corresponding requirements for acceptable levels of safety in the aviation operational environment should be complemented by resilience in a positive organizational safety culture (Reason, 2011). Akselsson et al. (2009) classifies organizational safety culture into three groups:

1. Psychological aspect relates to the safety climate inherent and how people feel.
2. Behavioral aspect deals with how people act in the organization.
3. Situational aspect deals with the structural component of an organization and the safety management systems inherent.

The situational aspect of a safety culture also relates to policies, procedures, and management systems within the organization. The behavioral aspect is measured through peer observations, self-reporting and outcome measures. The psychological aspect is very critical and is measured by safety climate questionnaires to understand the employees' perception of safety (Akselsson et al., 2009). Attributes of a resilient safety culture in an organization are situational adaptability, institutional learning, continuous improvements, and cost effectiveness in operations (Shirali et al., 2016). A resilient safety culture is based on three factors namely psychological/cognitive capability, behavioral capabilities and managerial/contextual capabilities (Pillay et al., 2010).

Shirali et al. (2016) advocates for a need to anticipate, monitor, respond and learn to manage safety risks in a resilient organization by identifying, modelling and quantifying resilience. This enables safety professionals to identify the vulnerabilities in the organization safety culture framework and proffer continuous improvements. In the domain of safety science, a resilient safety culture is potentially evident in an organization, when proactive safety policies, procedures and

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practices enable it to have greater resistance to incidents and accidents, as well as being able to cope better when they occur (Hollnagel et al., 2011).

Other evidence of a resilient safety culture in an aviation organization can also be identified in the maximum intrinsic resistance to the adverse effects of operational vulnerabilities through the use of both reactive and proactive safety management measures (Reason, 2011). A resilient safety culture can also be sustained by the effective implementation of Safety Management Systems (SMS) which is a formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls (Akselsson et al., 2009; Stolzer and Goglia, 2015). SMS includes systematic procedures, practices, and policies for the management of safety risk (ICAO, 2013a; FAA, 2015b).

Within the scope of SMS, a positive safety culture is known to be reflected in proactive and resilient behaviors of personnel in an organization and also serves as indirect indicator of good organizational management factors (Schwarz et al., 2016). In an effective SMS environment, measuring the cultural attributes of a resilient safety culture such as commitment, cognizance and competence can provide continuous monitoring and improvements of organizational safety (Reason, 2011).

Setting goals, identifying activities to reach these goals, and improving performance are all sub-components of an SMS measurement process (Stolzer and Goglia, 2015). SMS requires measuring performance against pre-established performance level expectations and implementing changes to acceptable levels of safety in the organization (Stolzer et al., 2018). As part of the SMS measurement process, creating continuous loops of learning and improvement of safety procedures should be desired outcomes in a resilient safety culture under operational conditions (ICAO, 2013b; Paries et al., 2018)

There has been a global advocacy to shift from prescription-based safety management strategies among aviation certificate holders to a performance-based approach such as SMS to enhance operational flexibility and improve organizational safety culture (ICAO, 2013a; ICAO, 2013b). The shift has made State Safety Program (SSP) managers, and those in charge of safety oversight in particular, to mandate SMS implementation for aviation certificate holders in their respective jurisdiction (ICAO, 2013b). Currently, aviation certificate holders in the United States (U.S.) such as Part 121 Part 121 commercial airlines are mandated to have an SMS program (Electronic Code of Federal Register. Part 5, 2015). However, Part 141 collegiate aviation programs in the United States are not under any regulatory mandate to have an SMS program (FAA, 2015a).

However, some collegiate aviation programs have adopted the SMS voluntary program (SMSVP) facilitated by the Federal Aviation Administration (FAA) and are deriving immense safety benefits in terms of enhanced proactive safety risk management and resilience in the safety culture inherent in their operations (Adjekum, 2014). A certificate holder that satisfies all the rigorous requirements of SMSVP is recognized by the FAA and designated an *active conformance* status. In the *active conformance* status, the certificate holder is expected to use, monitor and continually improve its safety management processes (FAA, 2015a).

As part of the regulatory certificate maintenance requirements for aviation personnel under SMS in the U.S., there is a need for strict conformity of practices with existing policies and procedures. This situation can pose a big challenge in a resilient safety culture environment which sometimes advocate for flexibility in operational procedures and avoidance of 'blind' following of rules in some extreme situations (Sheridan, 2008; Hollnagel, 2014). On one side this seems to be a smart way to reduce organizational vulnerabilities. On the other side, it is not always easy to develop solutions and implement measures for all predictable and unpredictable operational scenarios (Sheridan, 2008). In such scenario, adaptability may be required to sustain certain operations within margins of acceptable levels of safety (ALoS) (Reason, 2011; Hollnagel, 2014).

Despite strenuous efforts to ensure ALoS among "High-Reliability Organizations" (HROs) with SMS such as aviation, there is still un-anticipated safety risk in operational activities (Reason, 2011; ICAO, 2013a). 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 and Sutcliffe, 2007). HROs generically have resilient safety culture and Paries et al. (2018) in their research assessing HROs and SMS suggests some defining attributes of HROs, such as:

a. A high level of agreement by the whole staff on the core values of the organization, including recognizing safety as the primary objective.
b. A formal structure of roles and responsibilities with redundancies and overlaps, and a high level of empowerment of front-line operators to report abnormal events, adapt their behavior and even stop operations when imminent danger is perceived.
c. A clear map of relevant threats, risks and undesirable events, a wariness or permanent concern for risk, 'chronic unease' and a 'requisite imagination' of what could go wrong (un-anticipated safety risk).

With the challenges of controlling un-anticipated safety risks, it always behooves on HROs to make every effort to sustain a resilient safety culture using organizational resources that promotes a proactive safety system and prevent undesired safety events from re-occurring (Hollnagel et al., 2006).

Reason (2011) provides a conceptual model of a resilient safety culture engine that drives an organization's safety program based on the Degani and Wiener (1991) model of organizational management factors; *Principles, Policies, Procedures and Practices* (4P). The Reason model also utilizes attributes of the situational aspect of a resilient safety culture which deals with the structure of the organization, its policies, procedures, and management systems. An effective SMS should promote a resilient safety culture and use organizational management factors to continuously monitor safety performance due to periodic changes and potential perturbations in the operational environment (Schwarz and Kallus, 2015; Adjekum, 2017).

The relationships between organizational management factors, resilient safety culture and SMS within the scope and complexity of an organization's activities are captured in the *Resilient Safety Culture Bridge Model* shown in Fig. 1. The four pillars of an SMS program (Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion) (ICAO, 2013a) serve as the base foundation for safety in an organization while the upper suspension members holding the retaining wires are the inherent organizational policies.

The secondary supporting curved structural members in the bridge diagram are *Procedures* which reinforce operational practices at the "sharp-end" during organizational activities. *Principles* usually not easily recognized by personnel at the operational level in an organization are the underlying members/structures supporting *Practices*, *Procedures* and *Policy*.

The region between *Policy* and *Principles* is termed the safety resilience zone and suggests how far the organization can stretch operational goals while counterbalancing it with safety without a serious incident or accident. The area between the yellow dashed lines and the dashed red lines is the region of safety vulnerability. Within this region, the commensurate level of safety to cover exceptionally high operational activities is very minimal. If the suspension bridge were to continue stretching beyond the yellow region due to high-loading or external/environmental variables and exceeds the retaining capabilities of the suspension wires/ structural members, there could be structural failure with catastrophic outcomes. There may also be times when external variables such as wind gust or high tides can raise the water level (blue waves) to the red and yellow region and affect the structural

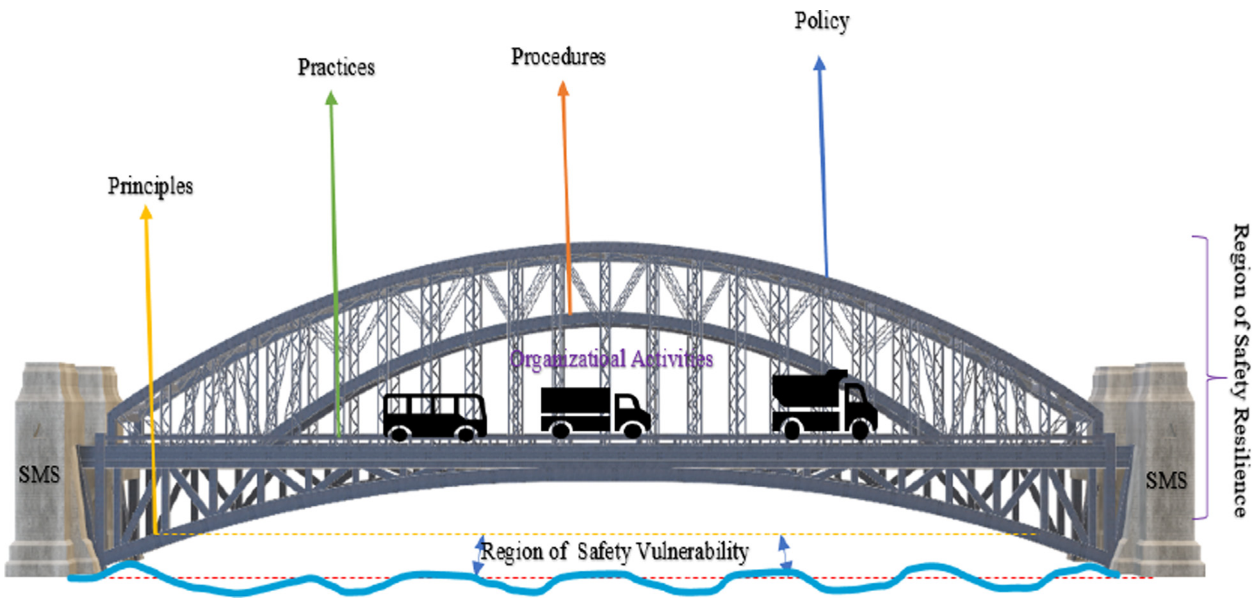

Fig. 1. Resilient Safety Culture Bridge Model (Source: Author based on Reason, 2011).

resilience of bridge.

The analogy is that an organization's measure of safety resilience is at risk of losing its elasticity within the region of safety vulnerability as per Hooke's law (Phys.org. 2015). Within this region risk from operational hazards cannot be considered as low as reasonably practical (ALARP) and continuous operations may weaken existing safety defenses, increase accident potential and ultimately lead to organizational accidents (ICAO, 2013a; Stolzer and Goglia, 2015). Adverse changes in financial status, national policies, quality of human resources, leadership attrition and high–tempo operational activities can induce safety vulnerabilities that increases the accident potential of an organization (FAA, 2015b; Adjekum, 2017).

Even when adverse events occur, an organization with a resilient safety culture has the capacity to adapt operational strategies, successfully recover, and operate effectively within margins of safety (Hollnagel, 2014). It is important that an organization with a resilient safety culture measure the behavioral aspect of safety resilience periodically through peer observations, self-reporting and outcome measures. The psychological aspect of safety resilience is very critical and should be measured by survey instruments to understand the employees' perception of safety resilience (Akselsson et al., 2009). Finally, the relationships between these three factors of a resilient safety culture in an aviation organization with an SMS should be explored and measured.

1.1. Research objectives

Assessing resilience in the safety culture of a collegiate aviation program that has an *active conformance* level SMS program is essential. Extant research suggests a lack of validated research instrument to assess safety resilient culture in U.S. collegiate aviation programs with an *active conformance* SMS. Previous studies on resilient safety culture in aviation have focused on commercial aviation, military and air traffic control environments (Akselsson et al, 2009; Hollnagel, 2009; Heese, 2012; Reason, 2011; Hollnagel, 2014; Paries et al., 2018) with minimal to almost no studies conducted on aviation training organizations such as collegiate aviation programs in the U.S. There is also a gap in studies that explore the relationships between resilient safety culture and organizational management factors (4 Ps) in U.S. collegiate aviation programs.

The primary aim of this study was to validate a survey instrument that assesses the relationships between a resilient safety culture and organizational management factors (4 Ps) in collegiate aviation programs in the United States. The effectiveness of measurement models that shows the relationships between resilient safety culture and measured attributes of organizational management factors in a collegiate aviation program with SMS were assessed using Structural Equation Models (SEM) such as Confirmatory Factor Analysis (CFA) and Causal Path Analysis (CPA). The strength of relationships between the organizational management factors *Policy*, *Principles*, and *Practices* when mediated by the *Procedures* in a collegiate aviation program with SMS were also explored.

1.2. Research questions

The following research questions based on the research objectives were answered in this study:

1. What is the effectiveness of measurement models of organizational management factors (*Principles*, *Policy*, *Procedures* and *Practices*) which relates to a resilient safety culture in a collegiate aviation program with SMS?
2. What is the strength of relationships between the organizational management factors (*Policy*, *Principles*, *Procedures*, and *Practices*) and the overarching construct resilient safety culture in a collegiate aviation program with SMS?
3. What is the strength of relationships between organizational management factors *Policy*, *Principles*, and *Practices* when mediated by the *Procedures* in a safety resilient culture environment of a collegiate aviation program with SMS?

2. Theory

2.1. High reliability organization (HROs) and resilient safety culture

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

Extant research in safety science shows that accident rates in "ultrasafe" 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, eliminating all failures can be a challenge. This supports the assertions that accidents are inevitable in complex, tightly coupled systems (Perrow, 1984; Leveson et al., 2009). That is why the connection between a resilient safety culture and SMS becomes very relevant to be able to proactively identify vulnerabilities in such organizations (Reason, 2011).

The concept of a resilient safety culture within the aviation operational environment has been fairly studied through extant research (Akselsson et al, 2009; Hollnagel, 2009; Heese, 2012; Reason, 2011; Hollnagel, 2014; Schwarz and Wolfgang, 2015; Schwarz et al., 2016). Generically, the findings of these research strongly advocate for the building of a resilient safety culture as part of an effective SMS program. Intuitively, a core foundation for sustaining a resilient safety culture in HROs is building resilience into all aspects of operations.

Hollnagel, Paries, Woods, and Wreathall (2011) defines resilience as "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances so that it can sustain required operations under both expected and unexpected conditions" (p. xxxvi). Hollnagel (2014) further posits that 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 a resilient safety culture.

Hollnagel (2014) position on safety resilience may sometimes pose a challenge for aviation service providers in the U.S. who still have to meet the requirements for strict regulatory compliance and formalism needed for certificate maintenance under a performance-based safety approach such as SMS (FAA, 2015b). Such strict conformity of policies, procedures and practices, can pose a big challenge in a resilient safety culture system which sometimes advocate for flexibility in operational procedures and procedural adaptations of existing rules in some extreme situations (Sheridan, 2008; Dekker, 2014). On one side this seems to be a smart way to reduce organizational vulnerabilities. On the other side it is not always easy to develop solutions and measures to be implemented for all predictable and unpredictable operational scenarios (Sheridan, 2008).

Oliver et al. (2017) suggests that HROs may hold important lessons for other organizations as they tread a path for developing safety resilient capabilities aimed at minimizing errors and failure. They also suggest that controllers of complex systems, whether they are pilots or executives, run the risk of becoming isolated from the systems that they oversee due to separation from front-line operations, such as when responsibilities are delegated to units who largely follow established protocols. This can result in organizational mindlessness (Weick et al., 1999; Sutcliffe et al., 2016).

Oliver et al. (2017) further posits 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.

In their research on resilient safety culture within the healthcare industry, Smith and Plunkett (2019) posits that a key factor in the understanding of safety within organizations relates to the distinction between 'work as imagined' and 'work as done' as originally proposed by Hollnagel (2009). 'Work as imagined' assumes that if the correct standard procedures are 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.

Smith and Arfanis (2013) suggest that nurturing both individual and organizational safety resilience culture must be considered fundamental to the safe delivery of healthcare. Smith and Plunkett (2019) argue that positive adaptability within systems that allows good outcomes in the presence of both favorable and adverse conditions are the metrics of systems resilience.

Paries et al. (2018) using a generic taxonomy of safety management modes, developed during a field study conducted within the French Air Navigation Service Provider (ANSP), found out that formal SMS implementation did not include many of the HROs features, while 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. They further suggest that a major effect of SMS implementation has been the introduction of copious amount of formalism (processes, procedures, and traceability), making safety management a much more centralized, systematic, normative, and bureaucratic process, often at the expense of qualities considered desirable by the HROs. Paries et al. (2018) further suggest a need to validate models on the relationship between SMS and safety resilience to reduce operational risks and improve safety.

Contemporary operational task in aviation is often complex so it can be difficult to predict all accident scenarios or situations. Safety resilience is therefore geared towards being able to deal with unexpected situations in an efficient and effective manner (ARPANSA, 2020). A resilient safety culture shifts the focus towards something more achievable which is having an ability to function safely or in the best way possible, regardless of the specific conditions experienced by the organization (ARPANSA, 2020).

Reason's conceptual safety space model of resilience (Reason, 2011) advocates for a safety culture that continues to drive an organization towards maximum practical resilience regardless of the commercial concerns of the current leadership by using an effective SMS program backed by sound organization management factors such as the 4Ps. Reason (2011) further suggest that the SMS program must use safety information system that collects, analyses and disseminates information regarding accidents, incidents and near misses to assure continuous improvement of operational processes.

2.2. Safety management systems voluntary program (SMSVP)

The FAA provides technical assistance to certificate holders who want to be part of the SMSVP (FAA, 2015b). Most of the collegiate aviation programs implementing an SMS program in the U.S. fall under this category (UND, 2012). As part of the SMSVP, a certificate holder is still mandated to follow existing regulations and certificate requirements. The FAA certificate maintenance office (CMO) monitors the certificate holder's conformity with the SMSVP standards once the SMS is recognized (FAA, 2015a). The following categories denote the progress expected from the SMSVP participants:

The first level of *SMSVP Active Applicant* is when the certificate holder and certificate maintenance team (CMT) have committed to sufficiently support the SMS implementation and validation processes.

The second phase of *SMSVP Active Participant* is the actual level, where the certificate holder officially begins SMS implementation efforts.

The third level of *SMSVP Active Conformance* is attained when the CMT and SMS program office (SMSPO) acknowledge full implementation of the certificate holder's SMS. The CMT is expected to use organizational factors to build a strong safety resilience culture aimed at reducing vulnerabilities.

2.3. Perceptions on resilient safety culture and impact on SMS

Previous studies indicate gaps in perceptions of personnel on attributes of a resilient safety culture after SMS implementation in the aviation operational environment (Patankar, 2003; von Thaden, 2008; Chen and Chen, 2011; Adjekum, 2014; Adjekum et al., 2016). Even with SMS, organizational management factors influenced by higher-level decisions can easily lower safety margins, create latent unsafe conditions and pre-disposes an organization to safety vulnerabilities (Reason, 1997; 2011).

These latent conditions weaken existing system safeguards and can aggravate the severity of unsafe act by “sharp-end” personnel (Reason, 1997; Dekker, 2014). It is therefore very important to continuously monitor, assess and improve SMS processes to minimize these perceptual gaps. Assessing the resilience of the safety culture provides vital information required by safety professionals in an organization to keep operational activities within the safety risk tolerability region, where hazards are proactively identified, risk analysis are performed and controls are implemented (Stolzer et al., 2011; ICAO, 2013a). Assessments of resilient safety culture as part of continuous monitoring and improvements of SMS may position an organization to better cope well with the unexpected. Reason’s attributes of organizational management factors and their relationships with a resilient safety culture in an organization with SMS best provides a theoretical framework for this study.

3. Material and methods

3.1. Research design

A quantitative research design involving an online anonymous survey was used to elicit the perceptions of respondent on items that measure the relationship between organizational management factors and resilient safety culture in a collegiate aviation program. The survey instrument for the study was developed from Reason’s attributes of an organization with a resilient safety culture (Reason, 2011) and initially consisted of 40 items (5-point Likert scaled with 1 = strongly disagree to 5 = strongly agree).

An initial face and 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 content validity review, some minor changes in items sequencing were done. As part of a power analysis, a sample size greater than 300 was recommended as expedient for meaningful effects and acceptable fit of the measurement model based on Kline (2005) SEM recommendations using model parameters.

3.2. Survey administration and data collection

Approval for the research protocols was obtained from the University of North Dakota Institutional Review Board (IRB) and a purposive sampling approach was used to send an anonymous online survey link via email to all personnel (aviation students, certified flight instructors, faculty, maintenance personnel, dispatch, administrative, and top-management) in a collegiate aviation program located in the Mid-Western part of the United States. The aviation program has one of the largest fleet size and student populations in the United States and has attained *active conformance* under the FAA SMSVP.

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. Relevant demographic data to assist in understanding the population was collected and highlighted in the descriptive data analysis in this paper but was used in another study aimed solely at effects of demographic variables on resilient safety culture in an aviation organization.

3.3. Criteria for data analysis and selection of test statistics

3.3.1. Multivariate normality criteria

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 normality plots of histogram and kurtosis/skewness values. The descriptive statistics did not show any extreme values for the kurtosis or skewness (values not larger than +/- 1). Since the sample size used for analysis were sufficiently large (n = 516) and there were no severe indications of non-normality in data that warranted transformations, multivariate normality was assumed (Field, 2018). All *p*-values were set apriori at 0.05 (2-tailed).

3.3.2. Model fit indices criteria

The responses of participants were used to conduct first-order CFA that would determine the strength of relationships between measurement scale variables (items) and their factors by determining how models fit the empirical data. A large class of omnibus tests exists for assessing how well measurement models matches observed data. The chi-squared (χ^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 χ^2 test may also be invalid when distributional assumptions are violated, leading to the rejection of good models or the retention of bad ones (Stevens, 2002; Brown, 2006; 2015). Carmines and McIver (1981) recommends calculating the relative *chi-square* (CMIN/DF) and suggest a ratio of approximately five or less 'as beginning to be reasonable’ or a range of 2 to 1 or 3 to 1 as indicative of an acceptable fit between the hypothetical model and the sample data.

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, p.86).

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). TLI may be interpreted in a similar fashion as CFI but can have a value outside of the range of 0 to 1 (Brown, 2006). 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 0.05 or below, and CFI and TLI are 0.95 or greater, the model may have a reasonably good fit. Therefore, it is recommended to not only report χ^2 but RMSEA and CFI/TLI. In this study, the TLI, $\chi 2$, RMSEA, CFI, NFI and IFI were reported for measurement models and final structural model. If the model fit was not satisfactory, a post hoc analysis was performed to modify the CFA model to produce a better fit. Items with high error covariance were eliminated as necessary.

3.3.3. Reliability and validity criteria

Cronbach’s alpha and composite reliability (CR) coefficients were used to assess the reliability. A Cronbach’s alpha of 0.7 or higher indicates good reliability of measured items (Nunally, 1978). In addition, a CR of 0.7 or higher also suggests good reliability, indicating internal consistency exists and means all measures represent consistently the same latent construct (Hair et al., 2011). The survey instrument was assessed for convergent and discriminant validity. A comparison of the factor loadings/standardized regression weight (β) and average variance extracted (AVE) method was used to assess the convergent validity (Hair et al., 2011). A discriminant validity analysis was conducted using the Heterotrait-Monotrait ratio of correlations (HTMT) approach with a predefined criterion or absolute threshold of 0.90 as recommended by extant research (Gold et al., 2001; Teo et al., 2008; Henseler et al., 2015).

4. Results

4.1. Survey demographics

The collegiate aviation program has a relatively large population (N ~ 1695) and there were 519 responses (~31% response rate) at the end of the three-week survey period which is adequate for most internal online surveys (Tse-Hua and Xitao, 2009). Out of the 519 responses, 516 respondents went beyond the consent page and undertook the survey (99.42%) and 3 declined (0.58%). Out of the 516 positive responses, there were varying levels of response rates based on specific survey items. Generally, the response numbers as compared to the non-response suggest minimal response bias. The details of the demographic variable functional groups are outlined in Table 1.

There were 420 positive responses to the demographic item 'academic level' in the survey and 96 non-response. Within the positive responses, the result showed that majority of the respondents in the student's category were juniors (29.05%), followed by sophomores (27.62%), seniors (23.81%), freshmen (15%) and graduate-level (4.52%). It is important to note that some personnel in flight operations/dispatch and ground handling are also students and can also identify with variable 'academic level'.

Respondents were asked to provide details on their highest flight certification and ratings and the result suggest that majority of respondents were private pilot certificate holders (46.90%). Details of the flight certificate held are shown in Fig. 2. It is noteworthy that among the "other" responses were participants with Airline Transport Pilot (ATP) certification (7), Airframe & Power Plant (A&P) ratings (5), 1 participant with Airframe and Power Plant with Inspection Authorization (A&P IA) and 10 non-pilots. There were 49 non-responses.

Respondents were asked to provide their age as part of this study. There were 470 responses and results showed a mean age of about 23 years (M = 22.94, SD = 7.944) and median age of 20 years. Results also showed the modal class being the 20-year old respondents and the highest age being 67 years. In terms of the gender variable (n = 516), there were 396 male respondents (76.7%) as compared to 120 female respondents (23.3%). The IBM SPSS® 26 analysis function for "pair-wise deletion of missing data" was used for the preliminary data sorting. The full-information maximum likelihood approach using the IBM AMOS® V25 was used for model assessments (Enders and Bandalos, 2001).

Table 1
Functional Group of Respondents.

Functional Groups	Percentages (%)	Count
Student	71.30%	368
Management (Supervisory and Administrative Role)	3.68%	19
Maintenance	1.35%	7
Ground Handling	0.84%	4
Flight Operations/Dispatch	10.85%	56
Academic Faculty	3.68%	19
Did not answer	8.3%	43
Total	100%	516

4.2. Question one

What is the effectiveness of measurement models of organizational management factors (Principles, Policy, Procedures and Practices) which relates to a resilient safety culture in a collegiate aviation program with SMS?

4.2.1. Principle

A first-order CFA was conducted to evaluate the strength of relationship between a theorized set of nine measurement items and the latent construct *Principle*. 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 but do not calculate factor scores (Brown, 2006; 2015).

The effectiveness of the measurement model to produce an acceptable fit of data and determine the factor loadings was determined. *Principles* are a corner stone of policy framework, operational procedures and "sharp-end" practices in aviation organizations (Reason, 2011). It is determined by an organization's management and becomes a conclusive statement on how operations at the organization is conducted. A resilient safety culture in an organization has an impact on strategic principles, which may not always be clearly stated but will be inferred from procedures, policies and practices (Degani and Wiener, 1991). An example of a measurement item under *Principles* is "Safety is recognized as being everyone's responsibility not just that of the safety management team". Table 2 provides details of descriptive statistics of measurement items for *Principles*.

The R indicator beside Pri 7 means the item was reverse-coded and responses had to be recoded to ensure consistency with other items in the scale during the preliminary analysis. The items Pri 1 - "Safety issues are not considered at high-level meeting on a regular basis unless after a bad safety event" and Pri 10 - "Top level leadership periodically brainstorms new scenarios of failures that leads to incidents/accidents" were deleted after the first analysis due to very low loadings. However, the model fit was not acceptable and further iteration was done using the modification indices feature of IBM AMOS® V25 (Byrne, 2004).

Subsequently, Pri 4, Pri 6, Pri 7R, and Pri 8 were deleted for poor loadings as part of the post-hoc iteration using the modification indices and to ensure parsimony of scale items describing the latent construct. A final measurement model which produced the best fit for *Principles* among the other competing models had five items. (Model III). Table 3 provides details of the goodness-of-fit indices for the three models.

The standardized regression weight (β) and Square Multiple Correlations (SMCs) which is also known as R^2 were used to demonstrate whether items are meaningfully related to their purported latent factors (Brown, 2015). SMCs of an observed variable is the proportion of its variance that is accounted for by its underlying factor (Byrne, 2004; Field, 2018). There were no indications of cross-loading and the SMCs of measurement items are the squared standardized factor loading in CFA models (Brown, 2015). Table 4 shows the β and R^2 values of items.

4.2.2. Policy

A first-order CFA was conducted to evaluate the strength of relationship between a theorized set of nine measurement items and the latent construct *Policy* (M = 4.39, SD = 0.443). *Policy* guides specifications in which management describe how certain operations are to be performed. Management will have policy guidelines that described training, maintenance, line operations and personal conduct etc. They are developed based on the organization's strategic principles but further determined by commercial and operational factors (Reason, 2011). Example of an item under *Policy* is "Policies ensure that supervisory personnel are present throughout high-risk procedures" Table 5 provides details about the descriptive statistics of measurement items that

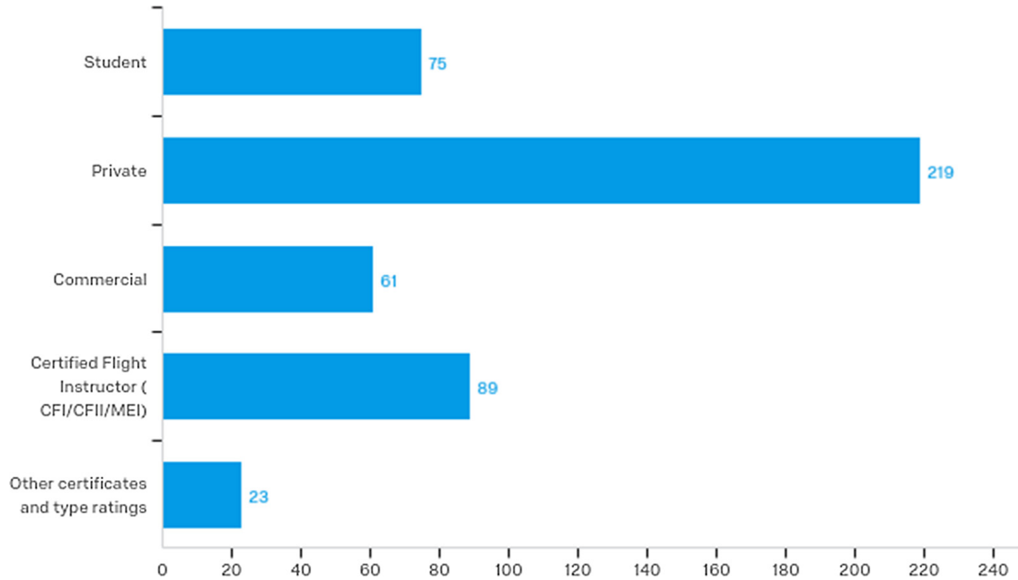

Fig. 2. Highest Flight Certificate/Ratings Held.

relate to *Policy*.

The R indicator beside Pol 8 means the item was reverse-coded and responses had to be recoded to ensure consistency with other items in the scale during the preliminary analysis. Pol 8R had to be deleted from the initial measurement model as the factor loading was low and affected the model fit. The post-hoc iteration using the modification indices of AMOS recommended the deletion. The second iteration required the deletion of item Pol 4 and covarying the error terms of items Pol 2 and Pol 3. The model was further improved by covarying the error terms between Pol 6 and Pol 7 to get the best fit. A final measurement model for *Policy* had seven items (Model III). Table 6 provides details of the goodness-of-fit indices for the various competing models. Table 7 shows the β and R^2 of *Policy*.

4.2.3. *Procedures*

Another set of first-order confirmatory factor analysis (CFA) was conducted to evaluate the strength of relationship between theorized set of measurement items in the survey and the latent construct *Procedure* (M = 4.68, SD = 0.034). Reason (2011) and Degani and Wiener (1991) suggest that procedures should be developed that are in line with an organization's principles and policy framework. *Procedures* should specify the nature of a task, time and sequence for conducting task, actions required, sequence of task and required feedback mechanism.

After the initial assessment of the measurement model, the fit was not acceptable and post-hoc iteration was done using the modification indices recommendations of AMOS. This was also guided by the theory underlying the relationships between items and the latent construct. Items Pro 6R and Pro 8R had to be deleted from the initial measurement model as their factor loadings were low and affected the model fit.

Another test was conducted and even though the emergent model had a relatively acceptable fit, the item Pro 2 was removed due to relatively low loading and to ensure parsimony. Another test was carried out and this produced a model that had a better fit index compared to the previous model. The final measurement model of *Procedures* had six items (Model II). Table 8 shows the goodness-of-fit indices for all models. The mean and standard deviations of scale items for *Procedures* is shown in Table 9 and Table 10 also shows the β and R^2 values.

4.2.4. *Practices*

First-order CFA was conducted to evaluate the strength of relationship between a theorized set of measurement items and the latent construct *Practices* (M = 3.74, SD = 0.777). Reason (2011) suggest that practices are the actual activities that occur at the 'sharp-end" of any organization and personnel are responsible for ensuring that these are in line with standard operating procedures (SOPs). However, deviations can occur when these actions differ from an organization's procedure. These deviations can be minor or major occurrences and, in some cases, lead to an accident.

An initial measurement model though acceptable required further improvement. A post-hoc iteration was done based on the modification indices. The measurement item Pra 6 – "Useful feedback on lessons learned from safety events are quickly put into practice by personnel" was deleted due to poor loading and a covariance between the error terms of Pra 3R and Pra 4 was introduced. A second model with better fit than the first was obtained after a re-run of analysis. A third competing model was assessed by introducing a covariance between the error terms of Pra 2 and Pra 4. The third model had the best fit among

Table 2
Descriptive Statistics of Items in *Principles*.

Measurement Items	Mean	Std. Deviation
Pri 2 - The safety mission statement is continually endorsed by top leadership's allocation of required resources human/financial/technological)	4.75	0.695
Pri 3 - Safety is recognized as being everyone's responsibility not just that of the safety management team	4.88	0.611
Pri 4 - Top management in my organization accept human errors as inevitable	4.40	1.139
Pri 5- Personnel understands that effective risk management depends on the dissemination of relevant safety information derived from analysis	4.79	0.594
Pri 6 - Lessons learned from past safety events are implemented as broad reforms rather than local repairs	4.50	0.945
Pri 7R - Top leadership blame specific individuals who were involved in accident/incidents rather than improving failed system defenses	3.75	0.744
Pri 8 - Top level leadership adopts a proactive stance towards safety	4.38	1.101
Pri 9- Top level leadership periodically brainstorms new scenarios of failures that leads to incidents/accidents	4.67	0.792
Pri 11 - Personnel at all levels look out for recurrent conditions/acts that leads to errors	4.74	0.737

Table 3
Goodness-of -Fit Indices for *Principles*.

Iteration	Chi Square (X^2)	NFI	IFI	TLI	CFI	RMSEA
Model 1	χ^2 (27, N = 516) = 41.298; CMIN/DF = 1.530, p = .039	0.851	0.892	0.821	0.889	0.048 (0.008- 0.057)
Model II	χ^2 (24, N = 516) = 35.538, p = .066, CMIN/DF = 1.481	0.915	0.979	0.965	0.973	0.032 (0.005 -0.058)
Model III	χ^2 (5, N = 516) = 6.048, p = .302CMIN/DF = 1.210	0.988	0.998	0.994	0.998	0.020 (0.000 -0.067)

Table 4
Standardized Regression Weight and Squared Multiple Correlation.

Measurement Item	(β)	R^2
Pri 2	0.734	0.539
Pri 3	0.709	0.502
Pri 5	0.574	0.329
Pri 9	0.703	0.494
Pri 11	0.640	0.409

(Note: all β are significant, p < .001)

the three competing models. The goodness-of-fit indices for *Practices* are shown in Table 11. Details of mean and standard deviation of measured items are shown in Table 12, and the standardized regression weights and SMC in Table 13.

4.2.5. Reliability and construct validity of survey instrument

The results from the various CFA models were used to assess the reliability, convergent validity, and discriminant validity of the four management constructs/factors underlying safety resilience. A Cronbach's alpha value of 0.7 or higher indicates good reliability of measured items (Nunally, 1978). In addition, a composite reliability (CR) of 0.7 or higher suggests good reliability and indicating internal consistency exists. It also means that all measures consistently represent the same latent construct (Chin et al., 2010; Hair et al., 2011).

Factor loadings and average variance extracted (AVE) methods were used to assess the convergent validity. A comparative approach was adopted in determining evidence of discriminant validity. The initial analysis compared the square root of AVE value of any construct with the correlation estimate between that construct with others (Fornell and Larcker, 1981; Chin et al., 2010; Hair et al., 2011). The square root of AVE value should be greater than the correlation estimates to provide good evidence of discriminant validity and the AVE value for each construct should be at least 0.50.

Extant literature also recommends the use of the Heterotrait-Monotrait ratio of correlations (HTMT) approach with either a pre-defined criterion/ absolute threshold of 0.90 as a confirmatory test for discriminant validity due to its high sensitivity (Gold et al., 2001; Teo et al., 2008; Henseler et al, 2015). HTMT is the average of the heterotrait-heteromethod correlations (i.e., the correlations of indicators across constructs measuring different phenomena), relative to the average of the monotrait-heteromethod correlations (i.e., the correlations of indicators within the same construct).

Table 14 shows the values of the Cronbach's alpha, CR, AVE and square root of AVE for all four factors. Both Cronbach's alpha and composite reliability values for *Principles, Policy* and *Procedures* were greater than 0.7, indicating good construct reliability. However, *Practices* had an acceptable Cronbach's alpha value and an adequate composite reliability. All the factors had an AVE ≥ 0.50 and above suggesting an acceptable convergent validity for the instrument.

Discriminant validity was inconclusive using the Fornell-Larcker approach and the inability to establish discriminant validity between two constructs does not necessarily imply that the underlying concepts are identical. Theoretical foundations and arguments should provide reasons for constructs correlating or not (Bollen and Lennox, 1991). According to the holistic construal process (Bagozzi and Phillips, 1982; Bagozzi, 1984), constructs are perhaps the most influential psychometric framework for instrument development and validation. However, they are not necessarily equivalent to the theoretical concepts at the center of scientific research (Rigdon, 2012; 2014). Table 15 shows the square root of AVE for each construct (bold) on the diagonal of table and the correlation coefficients among constructs.

The HTMT criterion 0.90 was used in a second analysis. Because HTMT is an estimate of the correlation between any of the two constructs in the analysis its interpretation is straightforward: if the indicators of these two constructs exhibit an HTMT value that is clearly smaller than one, the true correlation between the two constructs is most likely different from one, and they should differ. The $HTMT_{0.90}$ result suggests evidence of discriminant validity since the inter-construct correlation ratios were less than criterion 0.90. Table 16 shows the HTMT ratios among constructs and suggests a higher sensitivity of the HTMT method over the Fornell-Locker approach in assessing the discriminant validity (Henseler et al., 2015).

4.2.6. What is the strength of relationships between the organizational management factors (Policy, Principles, Procedures, and Practices) and the overarching construct safety resilient culture in a collegiate aviation program with SMS?

A hypothesized model that shows the relationship between the four management factors composed of principles on resilient safety culture (principles), policies on resilient safety culture (policy), procedures related to resilient safety culture (procedures) and practices related to resilient safety culture (practices) and latent construct resilient safety culture was assessed. The measured variable for the four factors were derived by summing the measurement items in each validated CFA model. The new variables were then used to assess the strength of

Table 5
Descriptive Statistics of Items in *Policy*.

Item	Mean	Std. Dev.
Pol 1: Aviation Safety Meetings are attended by personnel from a wide variety of levels/departments	4.68	0.814
Pol 2: Safety management issues are promptly attended to by top leadership without constraints	4.64	0.753
Pol 3: Top-level leadership have direct access to safety-related information on flight operations	4.74	0.626
*Po1 4: The organization prioritizes operational goals over non-operational demands whenever that is possible	4.22	1.028
Pol 5: Policies are in place to reduce potential sources of non-operational distraction in workplaces (ATC laboratory/ hangars/ classrooms/ flight-deck/offices)	4.63	0.841
Pol 6: Policies ensure that supervisory personnel are present throughout high-risk procedures.	4.67	0.72
Pol 7: There is a non-punitive safety reporting system in place (protections against sanctions for reporting safety hazards, events, and errors).	4.71	0.805
*Pol 8R: There is no confidentiality for personnel who report safety issues (safety reports are not de-identified by reporting system)	3.52	0.082
Pol 9: There are agreed standards for safety behaviors (acceptable/unacceptable)	4.73	0.841

* Items were later removed due to poor loadings

Table 6
Goodness-of -Fit Indices for *Policy*.

Iteration	Chi Square (X^2)	NFI	IFI	TLI	CFI	RMSEA
Model 1	χ^2 (14, N = 516) = 39.608, CMIN/DF = 2.829, p < .001	0.906	0.937	0.870	0.935	0.060 (0.038 -0.082)
Model II	χ^2 (13, N = 516) = 34.123, CMIN/DF = 2.624, p < .001	0.919	0.948	0.884	0.946	0.055 (0.033 -0.079)
Model III	χ^2 (12, N = 516) = 21.916, CMIN/DF = 1.826, p = .038	0.948	0.976	0.941	0.975	0.040 (0.009 -0.066)

Table 7
Standardized Regression Weight and Squared Multiple Correlation of *Policy*.

Measurement Item	(β)	R^2
Pol 1	0.638	0.407
Pol 2	0.680	0.462
Pol 3	0.732	0.536
Pol 5	0.658	0.433
Pol 6	0.507	0.257
Pol 7	0.619	0.383
Pol 9	0.653	0.426

(Note: all β are significant, p < .001)

relationships with the over-arching concept of resilient safety culture.

A bootstrap sample size of 5000 was used in this analysis. The analysis yielded an initial model with goodness-of-fit index as follows: χ^2 (2, N = 516) = 5.586; p = .061; CMIN/DF = 2.793; NFI = 0.985; RFI = 0.925; IFI = 0.990; TLI = 0.951; CFI = 0.990; RMSEA = 0.029 (0.015 - 0.057). An alternate model was examined as recommended by the modification indices function of AMOS 25. The new model required introducing a covariance between the error terms of *Procedures* and *Practices*. The goodness-of- fit indices in that iteration are as follows: χ2 (1, N = 516) = 0.009; p = .925; CMIN/DF = 0.009; NFI = 0.980; IFI = 1.010; TLI = 0.990; CFI = 0.998; RMSEA = 0.000 (0.000 - 0.040).

Both competing models had good fit to the data, but the second model was very much constrained, even though a perfect fit with the data was suggested. The first model which did not have any constrains was adopted over the second model based on theoretical considerations. Fig. 3 shows the final structural model of the relationship between the 4Ps and resilient safety culture and Table 17 shows the standardized regression weights, standardized direct effects, and squared multiple correlations.

The results show that *Policy* had the highest regression weight. On the contrary, *Practices* was the factor with the lowest regression weight. The total standardized direct (unmediated) effect of resilient safety culture on *Policy* was 0.877. That is, due to the direct (unmediated) effect of resilient safety culture on *policy*, when resilient safety culture goes up by 1 standard deviation, *Policy* goes up by 0.877 standard deviations. This is in addition to any indirect (mediated) effect that resilient safety culture may have on *Policy*. The results also suggest a good fit of the model to the data based on the all the goodness-of-fit indices especially the RMSEA value of 0.029 which was below the 0.050 threshold recommended by Kenny, Kaniskan and McCoach (2015).

4.2.7. What is the strength of relationships between organizational management factors Policy, Principles, and Practices when mediated by the Procedures in a safety resilient culture environment of a collegiate aviation program with SMS?

A causal path analysis was used to assess the strength of relationships between management factors when *Procedures* serves as a mediating variable between *Policy, Principles* and *Practices* within the context of resilient safety culture in a collegiate aviation program with an SMS. Reason (2011) suggest that the presence of clear procedures and compliance with such procedures can have an effect on how front-line personnel behave (practices) in a resilient safety culture environment. Procedures are tactical-level written documents that transforms organizational policy-framework primed by strategic principles into guidelines for processes.

The exogenous variables were *Policy* and *Principles* and endogenous variables were *Procedures* and *Practices*. The preliminary analysis of the fully mediated 4Ps measurement model as shown in Fig. 4 failed to produce any acceptable fit as evidenced by the fit indices: χ^2 (0, N = 516) = 0.000; p = not computed; CMIN/DF = not computed; NFI = 1.000; RFI = not computed; IFI = 1.000; TLI = not computed; CFI = 1.000; RMSEA = 0.265. The direct path from *Principles* to *Practices* produced a non-significant p-value and a small regression coefficient.

A post-hoc iteration was done on the fully mediated 4Ps model using the modification indices function to produce a better fit for the model. The direct path from *Principles* to *Practices* was then removed and a new analysis re-run. The resulting partially mediated model was better and produced a good fit as shown by the fit indices: χ^2 (1) = 1.175; p = .278; CMIN/DF = 1.178; NFI = 0.997; RFI = 0.968; IFI = 0.998; TLI = 0.995; CFI = 0.998; RMSEA = 0.019 (0.000 -0.119).

The results suggest no significant direct relationship between *Principles* and *Practices* although *Procedures* significantly mediated the pathway between *Principles* and *Practices*. The standardized direct effects, the standardized total effects and the indirect effects were also computed for the partially mediated 4Ps model. The squared multiple correlations of *Procedures* and *Practices* were also determined and are shown in Table 18. Fig. 5 shows the partially- mediated 4Ps and resilient safety culture model.

The highest significant standardized direct (unmediated) effect was that of *Policy* on *Procedure*, which was 0.633. That is, due to the direct (unmediated) effect of *Policy* on *Procedure*, when *Policy* goes up by 1 standard deviation, *Procedure* goes up by 0.633 standard deviation. This is in addition to any indirect (mediated) effect that *Policy* may have on *Procedure*. The standardized total (direct and indirect) effect of *Policy* on *Procedure* is 0.521.

The standardized indirect (mediated) effect of *Policy* on *Practices* was 0.222. That is, due to the indirect (mediated) effect of *Policy* on *Practices*, when *Policy* goes up by 1 standard deviation, *Practices* goes up by 0.222 standard deviation. This is in addition to any direct (unmediated) effect that *Policy* may have on *Practices*. There was a high estimated correlation between *Policy* and *Principles* (r = 0.726) and it was estimated that the predictors of *Procedure* explained 56.2 percent of its variance (R^2 = 0.562). In other words, the error variance of *Procedure* was approximately 43.8 percent of the variance of *Procedure* itself. The predictors of *Practices* explained about 30.4 percent of its

Table 8
Goodness-of -Fit Indices for *Procedures*.

Iteration	Chi Square (X^2)	CMIN/DF	NFI	IFI	TLI	CFI	RMSEA
Model I	χ^2 (14, N = 516) = 56.767p < .001	4.054	0.932	0.998	0.894	0.947	0.070 (0.057 -0.098)
Model II	χ^2 (9, N = 516) = 21.473,p = .011	2.386	0.965	0.979	0.951	0.979	0.052 (0.024 - 0.080)

Table 9
Mean (M) and Standard Deviation (SD) for *Procedures.*

Item	Items label	*M*	*SD*
Pro 1	Procedures are in place within the organization to facilitate continuing professional development of personnel	4.73	0.755
Pro 2	Procedures are in place to ensure that personnel under training attain pre-established competency standards	4.72	0.819
Pro 3	Trainees receive positive mentoring from instructors	4.55	1.029
Pro 4	There are standard operating procedures for recovery from errors recognized which are reinforced by training	4.79	0.689
Pro 5	There are comparable procedures in place to ensure safe transitions from the normal to emergency status (vice-versa)	4.64	0.004
Pro 6R	Personnel are not informed by feedback on recurrent error patterns in operations	3.25	1.527
Pro 7	Before any complex/unusual procedures, operational teams are briefed accordingly	4.65	0.797
Pro 8R	Operational supervisors hardly provide training on mental skills required to achieve safe performance in operational activities	2.91	0.819
Pro 9	Operational teams are debriefed after a task where necessary	4.55	1.029

Note: R means the item was reverse-coded and recoded during analysis to ensure consistency.

Table 10
Standardized Regression Weight and Squared Multiple Correlation for *Procedures.*

Measurement Item	(β)	R^2
Pro 1	0.786	0.617
Pro 3	0.589	0.346
Pro 4	0.718	0.515
Pro 5	0.722	0.521
Pro 7	0.698	0.490
Pro 9	0.686	0.470

(Note: all β are significant, $p < .001$)

variance ($R^2 = 0.304$)

4.2.8. Confirmatory analysis of 4Ps model using the PROCESS® method

The 4Ps model was further assessed using the PROCESS® V.3.4 in SPSS version26 developed by Hayes (2018) using a bootstrapped sample of 5000. The PROCESS program is an add-on option in SPSS version 26 for multivariate analysis of data. The bootstrapped corrected accelerated (BCa) confidence interval (CI) was also determined. The result suggests a significant predictive relationship between *Principles* and *Procedures* [t (330) = 4.75, SE = 0.060, p = .000, β = 0.25, 95% BCa CI (0.169 -0.408)] and significant predictive relationship between *Policy* and *Procedure* [t (330) = 8.89, SE = 0.054, p = .000, β = 0.47, 95% BCa CI (0.374 -0.587)] with *Procedure* as the outcome variable. The overall model was statistically significant [F (2,327) = 118.28, p = .000, R^2 = 0.42].

The mediated model with *Practice* as the outcome variable though statistically significant did not yield higher regression weights for the various paths. The overall model [F (3,326) = 11.91, p = .000, R^2 = 0.10] was not better compared to the initial model. The coefficients of *Principles* [t(330) = 1.23, SE = 0.065, β = 0.10, p = .219, 95% BCa CI (0.208 - 0.048)] as compared to *Procedures* [t (330) = 2.61, SE = 0.057, β = 0.20, p = .009, 95% BCa CI (0.037 - 0.262)] and *Policy* [t(330) = 3.01, SE = 0.062, β = 0.22, p = .007, 95% BCa CI (0.065 - 0.310)] validated the elimination of the direct path between Principles and Practices to get a better fitting model. The confirmatory analysis using PROCESS® also suggested *Procedures* significantly mediated the effect of *Policy* on *Practices* but did not mediate the effect of Principles on Practices.

5. Discussions and conclusion

5.1. Resilient safety culture model and instrument

This study aims at assessing and validating the relationship between a resilient safety culture and four organizational management factors (*Principles, Policy, Procedures and Practices*) in a collegiate aviation program with an *active-conformance* SMS. The hypothesized relationship was based on Reason's safety space concept of safety resilience in HROs (Reason, 2011). The results showed that the survey instrument used to assess the measurement models for the organizational management factors had good reliability and construct validity.

The structural model showing the relationships between resilient safety culture in the collegiate aviation program and 4Ps had a good fit with the empirical data and criteria outlined in extant literature. Both the standardized regression weights and squared multiple correlations of these factors suggest a relatively strong predictive relationship with the over-arching construct of resilient safety culture. In order of magnitude, the factors with the highest predictive relationships with resilient safety culture in the collegiate aviation program were *Policy*, *Procedures*, *Principles,* and *Practices*.

A strategic management implication of this study is that a resilient safety culture is strongly influenced by the policies, procedures and principles within an organization. This study also suggests that periodic assessments should be conducted to identify gaps and weaknesses related to these factors that can adversely affect the continuous improvement of safety resilience among personnel. This study supports earlier suggestions by Akselsson et al. (2009) and Hollnagel (2014) that there should be more consistent measurement of a resilient safety culture in aviation operations. The validation of the assessment instrument on resilient safety culture further supports the utility of Reason's conceptual framework on the relationships between organizational management factors and a resilient safety culture in an organization (Reason, 2011). These findings are also consistent with the need for robust organizational policies and procedures that are primed by an over-arching principle to ensure safe and highly resilient flight operations (Degani and Weiner, 1991).

The relatively weak relationship between *Practices* and resilient safety culture as compared to the other organizational factors could be attributed to inadequate awareness of resilient safety culture practices within the collegiate aviation program by some research participants. This can potentially affect their perceptions and responses to items

Table 11
Goodness-of -Fit Indices for *Practices.*

Iteration	Chi Square (X^2)	CMIN/DF	NFI	IFI	TLI	CFI	RMSEA
Model I	χ^2 (9, N = 516) = 29.811 p < .001	3.312	0.858	0.897	0.744	0.890	0.067 (0.041–0.094)
Model II	χ^2 (8, N = 516) = 19.623p = .012	2.452	0.907	0.943	0.839	0.939	0.053 (0.023 –0.083)
–	χ^2 (7, N = 516) = 10.827 p = .146	1.546	0.949	0.981	0.939	0.980	0.032 (0.000 –0.068)

Table 12
Mean, Standard Deviation (SD) for *Practices*.

Measurement Item	Mean	SD
Pra1 - Personnel proactively discuss safety-related issues whenever the need arises	4.75	0.707
Pra 2 - Personnel normally stop work under situations in which they are inadequately trained/ inadequately supervised because they are empowered to do so	4.10	1.161
Pra 3R - Personnel use “short-cuts” to overcome (often chronic) systemic deficiencies in getting the job done	2.76	1.313
Pra 4 - Personnel get rewarded for bringing safety issues/ problems to the attention of their line management	3.88	1.276
Pra 5R - Personnel hardly use training/tools provided to recognize high-risk situations	3.38	1.511
Pra 7R - Personnel continue to work under situations in which they identify highly error provoking conditions because they are not empowered to stop	2.80	1.508

Note: R means the item was reverse-coded and recoded during analysis to ensure consistency.

Table 13
Standardized Regression Weight and Squared Multiple Correlation for *Practices*.

Measurement Item	(β)	R^2
Pra 1	0.418	0.174
Pra 2	0.398	0.158
Pra 3R	0.651	0.423
Pra 4	0.422	0.178
Pra 5R	0.633	0.400
Pra 7R	0.548	0.300

(Note: all β are significant, $p < .001$)

related to that factor. It is also possible that the specifics of practices expected in a resilient safety culture environment may be novel to some of these respondents.

This suggestion may be plausible since majority of the respondents are flight students and certified flight instructors with relatively lower operational and management experiences as compared to personnel in the airline or air traffic control operational environment, where relatively higher resilient safety culture practices have been observed (Akselsson et al., 2009). Another suggested reason may be the mismatch between the nominally prescriptive regulatory environment of collegiate aviation environment which mandates stricter conformity with existing rules and regulations and the performance-based SMS environment of Part 121 operations that allows for some flexibilities in operational practices (FAA, 2015a).

The weak relationship between organizational management practices and a resilient safety culture in the collegiate aviation operations may require attention from the program managers and the regulators since Sheridan (2008) and Hollnagel (2014) discourages the blind following of rules in some extreme situations that requires procedural adaptations to achieve safety and operational objectives. A recommendation for more resilient practices should not be misconstrued as an argument against strict compliance with existing regulatory standards under normal operational conditions.

An increased focus on practices recommended in resilient safety culture environments such as such as mindfulness and safety empowerment may be expedient as part of the safety promotion activities of the SMS as advocated by Sutcliffe et al. (2016) and Hollnagel (2014). Effective training and supervisory mentoring in resilient safety practices can enhance the capacity of personnel to build contingencies for situations that can have adverse impact on organizational missions and goals.

This training allows for safety risk awareness in the operational environments and provides the diffused authority and accountability to suspend activities when risk exceed tolerable levels required for a task (Akgün and Keskin, 2014). However, the regression weights of the other three factors suggests that a high proportion of variances in these organizational management factors can be predicted by personnel's perceptions of resilient safety culture within the collegiate aviation program at the *active-conformance* level of the SMS. That is suggestive of a collegiate aviation program that has principles, policies and procedures in place that promotes a resilient safety culture.

Table 15
Discriminant Validity Assessment using the Fornell-Larcker Method.

	Policy	Principles	Procedures	Practices
Policy	**0.707**			
Principles	0.720**	**0.721**		
Procedures	0.733**	0.669**	**0.707**	
Practices	0.477**	0.439**	0.549**	**0.741**

** Correlation is significant at the 0.01 level (2-tailed).

Table 16
Discriminant Validity using Heterotrait-Monotrait (HTMT) Ratio $_{0.90}$.

	Principles	Policy	Procedures	Practices
Principles	**0.90**			
Policy	0.76	**0.90**		
Procedures	0.82	0.88	**0.90**	
Practices	0.73	0.77	0.83	**0.90**

5.2. Mediated and partially mediated 4Ps models

The highest significant standardized direct (unmediated) effect was that of *Policy* on *Procedure*. There was a high correlation between *Policy* and *Principles* that underscores the important role that institutional principles have on policy framework of any organization. The results support literature suggesting that policy framework forges a consistent and pragmatic review of procedures for use by “sharp-end” employees in an organization. (ICAO, 2013a; Stolzer and Goglia, 2015).

There was a weak predictive direct relationship between *Policy* and *Practices* and an almost nil predictive direct relationship between *Principles* and *Practices*. This result suggests that within the collegiate aviation program, a majority of the respondents' perceptions on the link between principles and practices was not clear. A possible reason may be the abstract correlation of higher-level institutional principles normally not well propagated and applicability in terms of observed behavior within the operational environment. This finding reinforces the

Table 14
Reliability and Convergent Validity Assessment.

Construct/factor	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)	Square Root of AVE
Principles	0.77	0.78	0.52	0.721
Policy	0.74	0.74	0.50	0.707
Procedures	0.85	0.85	0.50	0.707
Practices	0.70	0.69	0.55	0.741

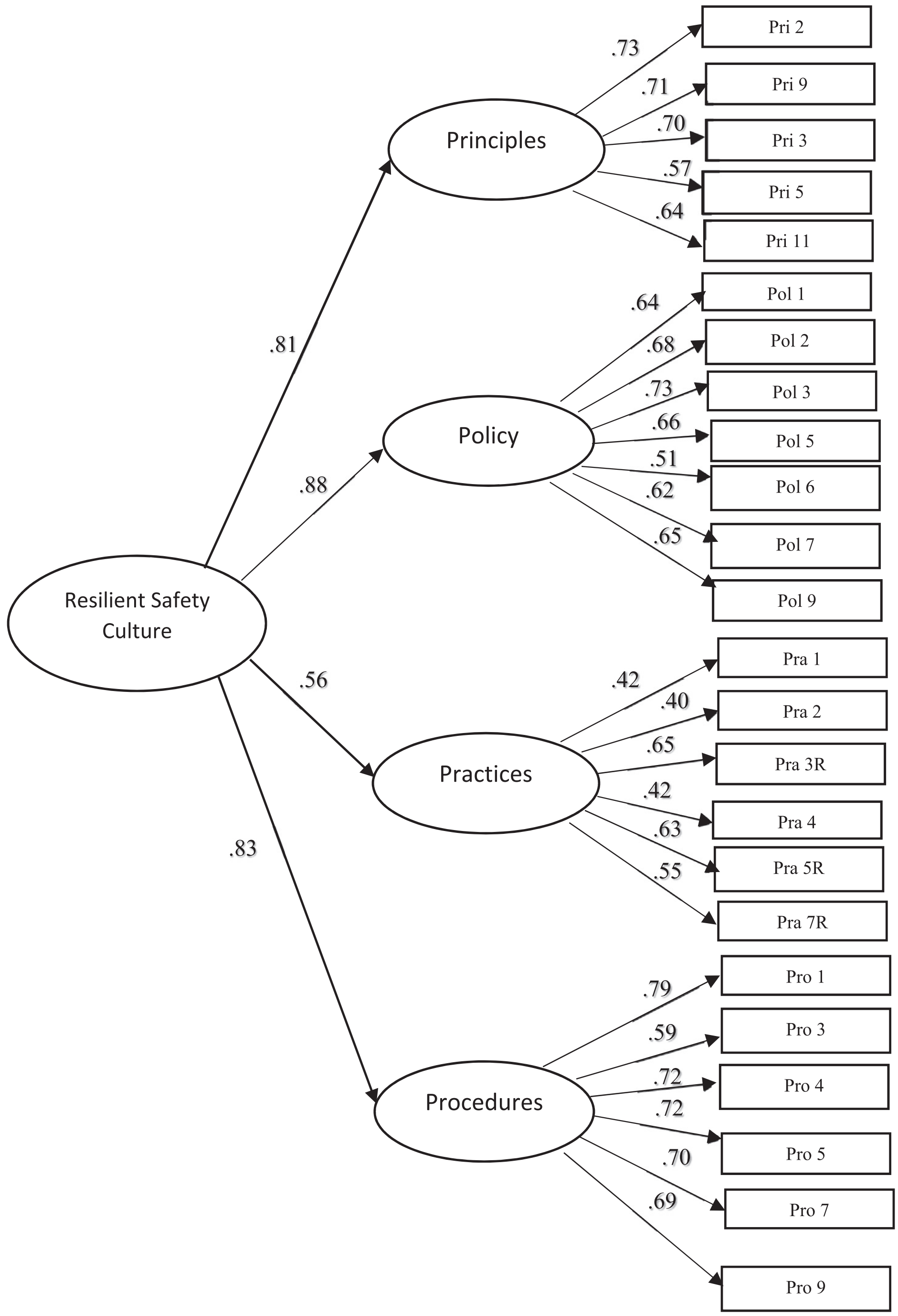

Fig. 3. Structural model of 4Ps and resilient safety culture ($p < .001$ for all β).

Table 17
Standardized Regression Weights (β), Standardized Direct Effects, Squared Multiple Correlations (R^2) for Safety Resilience Model.

Measurement Item	β	R^2	Standardized Total Effect
Principles	0.809***	0.654	0.809
Policy	0.877***	0.769	0.877
Procedures	0.833***	0.694	0.833
Practices	0.565***	0.319	0.565

Note: *** $p < .001$

notion that organizational management principles should be correctly framed within policy documents and further "practicalized" in standard operating procedures in order to have a meaningful impact on observed behaviors among front-line personnel. The strongest causal relationship was between *Procedures* and *Practices*. However, *Procedures* strongly mediated the path between *Policies* and *Practices*, which suggest that without comprehensive procedures outlining policies, sustaining resilient safety practices among "sharp-end" personnel such as CFI and flight students may be a challenge.

The relationship between *Policies* and *Practices* mediated by *Procedures* supports Hollnagel (2009) concept of 'work as imagined' and 'work as done' as two contrasting ways of understanding *Practices* at the "sharp-end". 'Work as imagined' is defined by the *Policies* and *Procedures* outlining the desired work process and represents how program leadership and supervisors believe work happens or should happen. 'Work as done', on the other hand, describes the work as carried out by 'front-line' employees at the 'sharp end'; in the case of collegiate

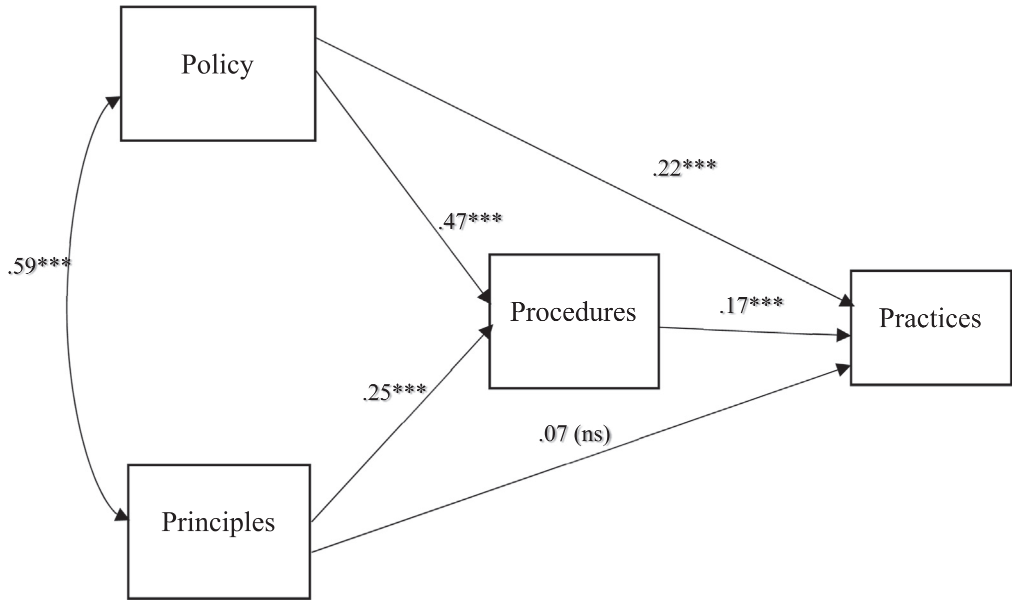

Fig. 4. Fully mediated 4Ps and resilient safety culture model. Note: *** p < .001; ns – non-significant; error terms omitted to ensure clarity.

Table 18
Standardized Effects of Mediated and Direct Paths and Fit Indices for Model I.

Standardized Total Effects	Principles	Policy	Procedures
Procedures	0.280	0.521	0.000
Practices	0.119	0.379	0.426
Standardized Direct Effects			
Procedures	0.366	0.633	0.000
Practices	0.000	0.245	0.547
Standardized Indirect Effects			
Procedures	0.000	0.000	0.000
Practices	0.119	0.222	0.000
R^2 = Procedure: 0.562; Practices: 0.304			

aviation, how flight students and instructors practically engage in flight training activities.

It may be reasonable to assume that although most flight students and instructors in the collegiate aviation program know the value of *Policies* and *Procedures*, operational exigencies and pressures may sometimes require them to improvise and work outside the 'rules'. This can have an influence on their perceptions on practices related to a resilient safety culture. Some variability in operational and safety resilient practices may also be observed because of the inherent risk and challenges posed by flight training factors such as:

a. Low flight experience of pilot trainees and high attrition of flight instructors to major airlines that can adversely affect "institutional memory" transfer.
b. Complexities of maneuvers performed as part of instructions (e.g. stall/spins/ engine-shutdowns and relights etc.).
c. Budgetary constraints that affects quality of training, safety oversight, operational activities and equipment state.

These variations could also be due to organizational conditions

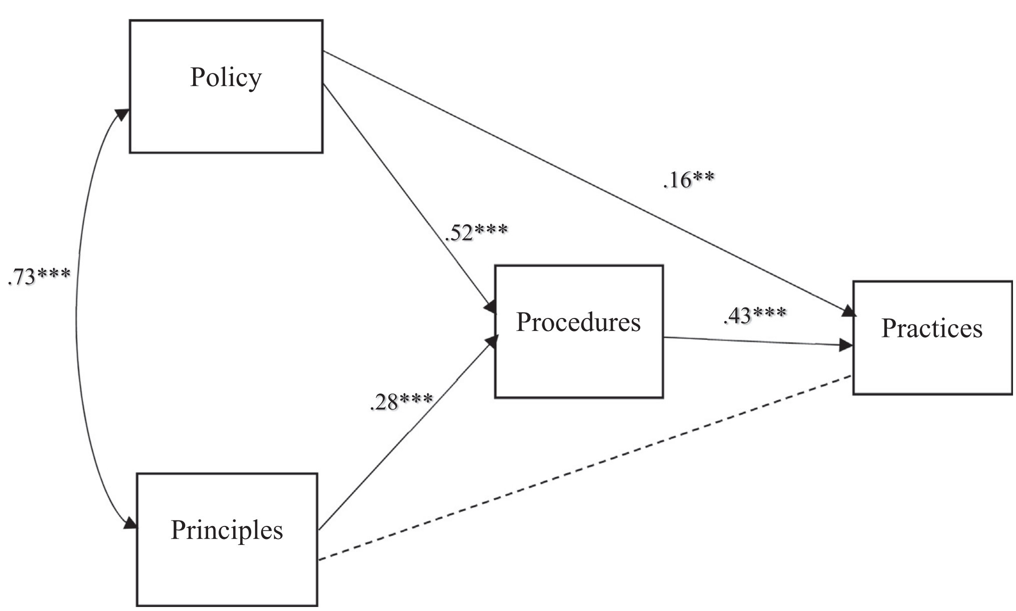

Fig. 5. Partially Mediated 4Ps and resilient safety culture Model. Note: *** p < .001; **p < . 005; error terms omitted to ensure clarity; path between *Principles* and *Practices* deleted.

created by those at the 'blunt end' (management); the *Policies* produced, or the way in which standards for *Practices* are perceived. The results also substantiate Paries et al. (2018) assertion that excessive attention to SMS formalism (policy, procedures, and traceability) may lead to bureaucratic processes, often at the expense of focusing on desirable resilient factors such as *Practices*. It is therefore essential for collegiate aviation programs to be extra mindful during high-tempo operational seasons and re-calibrate their policies and procedures to foster management practices that promotes a resilient safety culture.

5.3. Limitations and recommendations for future research

Responses were mostly from young collegiate aviation students with minimal exposure to a sustainable resilient safety culture. It is recommended that the inferences drawn from this study be limited to the study population and not generalized. Future research will further improve the reliability and validity of the research instrument by replicating the study in other collegiate aviation programs with and without an SMS. The use of the structural models in this study to assess safety resilience among collegiate aviation programs at varying stages of implementing the SMSVP is highly recommended.

Aviation entities such as commercial airlines, airports and air traffic organizations can also adopt the survey instrument to assess their resilient safety culture. A significant benefit of this study was the validation of a resilient safety culture survey instrument and proposal of a structural model on resilient safety culture for collegiate aviation programs with SMS. Another benefit was a framework that explored the relationships between resilient safety culture and four organizational management factors. Finally, this study adds to literature on resilient safety culture in collegiate aviation programs with SMS.

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