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Crew Resource Management Application in Commercial Aviation

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Abstract

The purpose of this study was to extend previous examinations of commercial multi-crew airplane accidents and incidents to evaluate the Crew Resource Management (CRM) application as it relates to error management during the final approach and landing phase of flight. With data obtained from the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB), a χ^2 test of independence was performed to examine if there would be a statistically significant relationship between airline management practices and CRM-related causes of accidents/incidents. Between 2002 and 2012, 113 accidents and incidents occurred in the researched segments of flight. In total, 57 (50 percent) accidents/incidents listed a CRM-related casual factor or included a similar commentary within the analysis section of the investigation report. No statistically significant relationship existed between CRM-related accidents/incidents

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and airline management-related cause was found. Nevertheless, the data provide support for the necessity of robust and strategically well-thought-out airline management implemented procedures and guidelines, used in modern aircrew training, in order to enhance pilot monitoring skills for an improved CRM application in commercial aviation.

Keywords: Crew Resource Management, commercial aviation, final approach, management, airline, accident

This study critically examined the potential influences of current Crew Resource Management policies in airline flight operations. It also analyzed management-implemented CRM guidelines and procedures in reference to their operational integration and adherence during the final segment of flight. Recognized scholarly studies were evaluated and conclusions are presented in reference to possible future production implementations of environmental display technologies in commercial aviation.

Crew Resource Management Application in Commercial Aviation

Travel on modern commercial airplanes is one of the safest modes of transportation. Due to this fact, when accidents involving air transport operations occur, they tend to attract a significant amount of attention. Moreover, mishaps involving large, commercial aircraft often are accompanied by significant numbers of fatalities. Even in light of the noteworthy technological advances in modern aircraft, devastating crashes continue to occur. The approach and landing phases of flight appear to be the most problematic, as these segments account for the majority of accidents (53 percent) while compromising a very small portion (4 percent) of total flight time (Spare, 2006b).

Investigations indicate that human error is a contributing factor in nearly 80 percent of all carrier incidents and accidents. Long-term research by the National Aeronautics and Space Administration (NASA) has revealed that these events share common characteristics. However, many problems encountered by flight crews have little to do with the technical side of working in a multi-crew cockpit. Instead, poor group decision making, ineffective communication, inadequate leadership, and deficient task or resource management have been related problems (Shappell et al., 2006).

Traditionally, pilot training programs concentrated almost entirely on the technical aspect of flying and on individual performance. Crew management matters, which also are fundamental to flight safety, were previously not effectively addressed (FAA, 2004). Certain phases of flight have higher requirements for coordination. One such operational segment involves approach and landing. Veillette (2004) found that flight crews failed to conduct stabilized approaches in 64.4 percent of the Approach and Landing Accidents (ALAs). In addition, from all those unstabilized ALAs, 81 percent included rushed approaches and 72 percent revealed inadequate crew coordination. According to a National Transportation Safety Board study, inadequate monitoring by flight crewmember(s) was a factor in 63 percent of ALAs (NTSB, 2004).

It is now understood that pilot error cannot entirely be eliminated. Therefore, it is crucial that flight crews develop proper Error Management (EM) skills and procedures. Error detection and recovery from errors should be reinforced in training (FAA, 2004) in order to mitigate flight safety occurrences. Effective Crew Resource Management (CRM) starts in initial training and is intensified by repetition and feedback. Therefore, EM must encompass a significant part of CRM training, while also being built into the corporate culture and continuously being emphasized in every subsequent phase of training (FAA, 2004).

Many global aviation safety organizations, including the FAA, have reconfirmed the significance of Standard Operating Procedures (SOPs) as essential to flight safety. Crews should have a shared mental model of each task because only then is effective crew coordination and crew performance attainable. SOPs have to be clear, comprehensive, and readily available in order to keep aviation operations standardized and reduce perceptual actions by the crew (FAA, 2003).

Crew Resource Management

Evolution/History

In the early 1950s, commercial aviation entered a period in which aircraft began to fly farther and faster with the widespread use of jet engines in airliners. Jet aircraft also provided more complexity in systems and operational procedures. Initially, additional risks that accompanied these changes were not obvious to the aircraft designers, engineers, or pilots. Fatal accidents increased and were highly publicized. In general, the causal factors included technical and mechanical issues, but the majority of the accidents were listed as pilot error. For the aviation industry to survive as a recognized and accepted mode of transportation, these problems would need to be mitigated. Improvements in aircraft equipment design as well as the implementation of electronic warning systems reduced the accident rate and, in many cases, also addressed human error. The technological solutions in conjunction with flight simulators helped the aircrews to reduce a degree of human error and better manage the errors that came about (Kanki, Helmreich, & Anca, 2010).

A pivotal occurrence took place in 1978 when a commercial airliner crashed when the flight crew mismanaged an airplane malfunction, lost situational awareness (SA), and ran out of fuel. The inability of this crew to work together and handle the additional workload triggered a philosophical change in the industry to focus on human factors training with specific concentration on leadership and decision making. CRM was born from this catastrophe; however, the first training concepts and courses were initially known under the term "Cockpit Resource Management." During the 1980s, one of the most striking developments in aviation safety was the overwhelming endorsement and widespread implementation of training programs aimed at increasing the effectiveness of crew coordination and cockpit management. During the mid-1990s, CRM was not universally accepted by the pilot community. It was sometimes decried as charm school, psychobabble, and attempted brainwashing by management (Kanki et al., 2010).

Presently, the industry is experiencing the sixth generation of CRM, which focuses on the threats and errors that must be managed by crews to ensure safe flight. Current CRM embraces not only optimizing the person-machine interface and the acquisition of timely, appropriate information, but also interpersonal activities including leadership, effective team formation and maintenance, problem solving, decision making, and maintaining SA. Therefore, training in CRM requires communicating basic knowledge of human factors concepts that relate to aviation and providing the tools necessary to apply these concepts operationally (Kanki et al., 2010). This research project aims to analyze the gathered data in exactly those areas, investigates if proper CRM procedures have been applied, and initially, if the accident/incident aircrews have received adequate guidance and/or training in order to apply proper CRM procedures.

Airline CRM Training

The most central element in airline operations is the respective air carrier's department of flight operations. Within this subdivision, a pivotal tool for the prevention of pilot error has been CRM. Over the years, CRM has expanded to integrate cabin crew as these individuals often can provide helpful information to pilots and must be kept informed in emergency situations. Current CRM training continues to offer key guidance on effective communication, task sharing, team building, and teamwork. Threat and Error Management (TEM) training endorses preemptive strategies of threat recognition, avoidance, and management. Both CRM and TEM require data from accidents and incidents as well as from Flight Operations Quality Assurance (FOQA) programs and Line Operational Safety Audits (LOSA). The most effective training platform for airlines today is the Line-Oriented Flight Training (LOFT) in which crews must fly a simulated flight scenario between two or more points. These scenario-based learning tasks involve a combination of modern, high-fidelity simulators and the conduct of normal flight operations procedures. LOFT provides the most realistic setting in which crew performance, in reference to the operational environment, can be measured. LOFT has been inadequately and infrequently applied and only recently mandated by some regulators (Salas & Maurino, 2010).

In order to reflect on the views of airline management, Salas and Maurino (2010) indicate that risk reduction can generate competitive advantage. Improved processes will guide greater efficiency, cost reduction, and improved system safety. New aircraft acquisition is relatively straightforward; however, the production of safe and well-trained flight crews is a more complex task. Minimum training standards approved by the regulator may not adequately prevent airline accidents. However, training is a controllable variable in the airline safety system, and wiser management teams will look for and apply the best practice. The potential cost increase for air carriers, with a contemporary CRM training update for flight crews, would be negligible if compared to the monetary loss of an aircraft, not even considering the catastrophic outcome and subsequent publicity (Salas & Maurino, 2010).

International Policies

Since the initial development of the airplane into a global instrument of transportation, air travel has encountered various challenges across the globe. The coordination of operational laws, procedures, and techniques is far beyond the capability of individual governments to solve. The standardization of internationally recognized services and procedures is a fundamental aspect of safe operations in the aviation industry in order to alleviate errors caused by misunderstanding or lack of experience. The organization of the standards—such as air traffic control, personnel licensing, and airport and airplane design—all require actions surpassing the national borders of individual countries. The Chicago Conference of 1944 established the International Civil Aviation Organization (ICAO) to advance the planning and development of international air transport in accordance with specific principles. The ICAO assembly is composed of one representative from each contracting state. Today, there are close to 200 members (Wensveen, 2007).

CRM application in commercial aviation around the world is as diverse as the cultures in which it has been implemented. First developed in the United States, its international migration has been varied. Ranging from welcoming approval to simple rejection, most CRM concepts traveled readily throughout different parts of the world. Kanki et al. (2010) distributed a survey to South American, Asian, and Middle Eastern airlines in order to gather a cross-section of the experiences their CRM developers and managers encountered. All of the pilot contributors had, on average, 8 to 15 years of CRM design and delivery experience. The following broad areas of CRM influences were selected: perceptions of CRM success in relation to local operations, the impact of TEM on CRM, and the future of CRM in the respective countries. The foremost responses about CRM success in programs outside the U.S. were concentrated on the new delivery format of training. Using line pilots as facilitators was widely accepted, but in strong hierarchical cultures the expectation was rather on a top-to-bottom delivery from management. However, having a current pilot instead of a training consultant as the facilitator made the program more credible, especially when focusing on EM, as the topics were then only discussed amongst peers (Kanki et al., 2010).

In addition, the biggest beneficiary in line operations was the co-pilot. In high power/distance cultures like China, Latin America, and some Asian countries, the importance and respect for rank, elders, and leaders is dominant. Nonetheless, in regards to their flight safety, the management of human error is most important. Therefore, by assuring and authorizing the First Officer (FO) to assert his/her concerns, the captain in a commercial multi-crew cockpit will only benefit from the FO's input and better manage the existing threats and errors. Implementation of TEM was welcomed as it focused more on a scenario-based problem than on a single human factor issue. However, the initial confusion about the role of TEM had to be overcome. Some believed it would replace CRM and some saw it as a critical update (Kanki et al., 2010).

Language differences are still considered to be the most challenging hurdle in proper CRM implementation outside the English-speaking countries. In general, the future of CRM outside the U.S., unfortunately, does not take the primary concern of some countries, especially in those outside the Western and English-speaking cultures. Without continuous influx of data, CRM can quickly turn into a bureaucratic obligation in the air carriers' annual training (Kanki et al., 2010).

Under the European Aviation Safety Agency (EASA), CRM is also known as Multi-Crew Cooperation (MCC) training, which requires completion before a type rating is issued. Current CRM training continuously provides key guidance on effective communication, task sharing, team building, and teamwork—utilizing appropriate flight deck behaviors for safe operations (Salas & Maurino, 2010).

Problem Identification

Controlled Flight into Terrain (CFIT) is one of the main aviation hazards addressed by aviation safety organizations around the globe. Exigent literature indicates that almost 50 percent of 107 recent CFIT accidents were related to failure of SOP adherence (FAA, 2003). In addition, several studies of crew performance, incidents, and accidents have revealed that insufficient flight crew monitoring is negatively impacting flight safety. Effective monitoring can be the last line of defense before an accident occurs as error detection can break the chain of events that result in dire consequences (FAA, 2004). Crew monitoring performance can be significantly enhanced by developing and implementing effective SOPs to support this function (FAA, 2003).

Seasoned pilots continue to have ALAs even with the availability of safe alternatives such as diverting to alternate airfields and initiating early missed approach maneuvers (Spare, 2006a). Clearly, experience level does not assure immunization against errors; conversely, experience can actually increase susceptibility to an ALA (Spare, 2006b). The true key to flight safety is to effectively manage these errors, thus preventing small errors from escalating to dangerous levels (Spare, 2006a). This is a collective crew effort and needs to be addressed in training, evaluation, and more importantly during operations—independently of who is actually committing the error versus who is detecting it.

Besco et al. (1994) pointed out that pilot error has been recognized in up to 80 percent of the airline accidents worldwide. However, this study already demonstrated that in almost all of those accidents, one of the most frequent recommendations had been to modify or increase the emphasis in the training programs for aircrews. This institutional problem is not to be underestimated and will also be examined with the latest training concepts in reference to EM and crew monitoring procedures.

Review of Relevant Literature

Error Detection and Prevention

According to an NTSB research study, as cited in Orasanu et al. (1998), the majority of the accidents where crew behavior played a role involved monitoring and challenging errors. After an error occurred, the crew either did not detect it or failed to communicate effectively in order to improve the outcome. In most of the accidents the captain committed the error as the pilot flying (PF) and the first officer (FO), as the non-flying pilot, failed to recognize and correct it. However, team structure advantage comes into play. Members can support each other, identify errors, and possibly avoid serious consequential results (Orasanu et al., 1998).

Orasanu et al. (1998) suggest two factors that influence the probability of monitoring and challenging errors in their study: the risk level associated with the developing situation and the extent of face threat involved in addressing an error with the other crewmember. In regards to the level of risk, the expectation was that for the more dangerous scenarios the crew's monitoring would be more precise than that for the low-risk situation. In reference to face threat, investigation focused on the degree of challenge to the status or integrity toward the other crewmember. The participants were all male Boeing 747 flight crews from the same U.S. airline. As anticipated, high face threat suppressed the error detection rate of the FOs. However, this was only noticeable in conditions of high risk. In general, captains were more perceptive to proper risk assessment in a particular situation, while the FOs were more concerned with a possible face threat within the cockpit. In sum, the FOs were clearly attentive to social implications of challenging the captains. For instance, when the situation called for a high-risk outside the cockpit, the FOs were very confident in pointing out the risk.

Conversely, if a high-risk level was noticed inside the cockpit, the FOs had a tendency to demonstrate somewhat weak detection of risk. During the subsequent flight debriefing, the FOs were generally expressing that they had been relying more on the expertise of the captain. The findings undoubtedly indicate that social aspects of even experienced aircrews play a crucial role in their performance. Evidently, more work is necessary in effectively communicating in high-risk situations, particularly in those that involve high face threat (Orasanu et al., 1998). Multi-crew cockpit crews require strategic procedures and guidelines on how to deal with socially sensitive challenges. Role-play, for example, is a seemingly suitable response where young and/or inexperienced FOs can practice developing assertiveness skills (NTSB, 2011). Yet the responsibility rests with airline management and training to steer crewmembers in developing the right attitudes in order to promote safe flight over social apprehension.

Threat and Error Management

Flight crew training

TEM stands for avoiding threats or opportunities for error. Moreover, it detects new threats or errors and decreases their effects, while at last it manages the consequences of any threat or error (Spare, 2006a). TEM training helps pilots to attain an enhanced level of performance that will permit them to deal with the increased challenges of sustaining safe flying operations (Gunther & Tesmer, 2001). Helmreich, Klinect, and Wilhelm (2001) developed a model of EM that distinguishes between five types of error: procedural error, communication error, proficiency error, decision error, and intentional non-compliance. Their research indicated that the highest percentage of errors (50 percent) involved intentional non-compliance, which included violations. Yet only 6 percent led to an undesired aircraft state. Quite the opposite case existed with lack of proficiency and decision error, as each accounted for only 5 percent of the errors, but around 60 percent of those were significant.

The descent, approach, and landing phase of flight account for the highest number of threats (36 percent) and errors (40 percent). The Continental Airlines' LOSA 2000, in relation to the one four years earlier, indicated a 70 percent reduction of unstabilized approaches. This unmistakably demonstrated that the 1997 implemented CRM training course in EM was not only accepted by the pilots, but also was integrated into their daily operations. LOSA data provides transparency into areas of need but also detects superior performance. Hence, rewarding outstanding behavior instead of punishing failure can provide powerful learning (Helmreich et al., 2001).

When aircrews successfully detect and acknowledge threats as red flags, they are in a better position to manage the threat so it becomes insignificant. Typically, accident crews do not recognize all the threats or their severity, which invites error and consequently increases workload (Gunther & Tesmer, 2001).

Applying TEM to ALAR

The Flight Safety Foundation encourages TEM as a means for Approach and Landing Accident Reduction (ALAR). Threats are not errors, but threats magnify the potential for error. Managing threats involves the following processes: threat avoidance, threat identification or classification, trapping the threat, and resolving or mitigating it. Apparently, unexpected threats are the ones that are the most dangerous. However, a detailed preparation in combination with an effort to obtain all accessible information concerning a situation reduces the probability of any unexpected threats (Spare, 2006a). Most importantly, any existing error in the approach path needs to be acknowledged first and then trapped before it creates a flight safety hazard.

Errors emerge as a result from past activities. They are effects and not causes. Usually, errors fall into two categories: an SA error, when incorrect interpretations of a problem result in a wrong decision, and a course of action error, where a correct perception is present but an inappropriate course of action is chosen (Spare, 2006b). A practical plan to alleviate errors during an approach-to-landing is to include the so-called approach gates. Those gates specify that certain parameters should be met at specific points along the route; otherwise, the pilots are forced into a different course of action, such as a go-around maneuver (Spare, 2006a). The FAA (2003) lists the exact parameters and limitations for a so-called stabilized approach. However, different airlines can always put a more restraining guideline in their own carrier SOPs.

Human Limitations in the Modern Automated Flight Deck

While there is an obvious increase in complexity of technology, the human role must change in order to keep up with the automation. In addition, for any mishaps, human limitations appear to be blamed more and more relative to the technology (Salas & Maurino, 2010). Air traffic is increasing and new automation will be implemented to enhance SA in order to mitigate aviation accidents. Even if all aircraft categories could benefit from enhanced and synthetic vision systems, they are presently not integrated in Part 121 and 135 regulations. The safety benefits of those enhancing systems are apparent during abnormal and emergency situations. Particularly in a high workload environment, they permit the pilots, through their intuitive displays and presentation methods, a possibility to off-load some of the basic special awareness tasking such as terrain and traffic avoidance (Prinzel & Kramer, n.d.). A future key capability in managing the amplified amount of air traffic is the concept of equivalent visual operations. Here, operational tempos and procedures in reference to Visual Flight Rules (VFR) are maintained, independent of the actual outside weather conditions (Kramer, Bailey, & Prinzel, 2009).

The FAA's Next Generation Air Transportation System (NextGen) is purportedly able to improve aviation operations, but also considerably change the jobs traditionally held by pilots and air traffic controllers. Changes in roles and allocation of function require new procedures, including ground and air responsibilities. Key to human performance is ensuring that design mitigates the potential for human error, recognizing that new automation and procedures may also introduce new sorts of threats and errors. Pilots and controllers will need to maintain SA under new and different operational circumstances; otherwise, without effective management of those threats and errors, they could easily find themselves in new undesired states (Salas & Maurino, 2010). Pilot and controller training, as well as strategic procedural guidance from upper management, will be crucial aspects in implementing NextGen. Additionally, an even more pronounced amount of trust in automation is required to help create a tighter traffic network. Autonomous pilot reactions to electronic warnings can be anticipated to minimize delayed reactions and also lessen workload of air traffic controllers.

Methodology

The proposed hypothesis is that, among accidents and incidents involving CRM, there is a significant difference between the proportion of management-related and non-management-related accidents/incidents of U.S. commercial multi-crew airplanes during the final approach and landing segment of flight. The null hypothesis is that there were no differences in the proportion of airline management-related and non-management-related accidents/incidents (McDonald, 2009). A detailed analysis of publicly accessible aviation accident/incident reports was performed in order to accept or reject the null hypothesis.

Data Review and Critique

After the review and critique of the collected data, a slight research design change had to be performed. The NASA Aviation Safety Reporting System (ASRS) online database was excluded from the originally proposed pool of data sources. From the 75 occurrences in the ASRS database during the past 10 years, 35 events were CRM-related. However, it was found that the ASRS reports appeared to be biased by their authors—many providing their own conclusions or suspected causes—so exclusion was necessary in order to obtain an objective statistical analysis. Even though the ASRS reports contain very valuable information for accident prevention and aircrew training enhancements, for the purpose of this study, only final versions of the NTSB accident and incident reports were considered. Therefore, all investigations on the researched mishaps had been completed prior to this project. As a result, due to the reduction in collected data, the scope was expanded to include the landing phase of flight. Many accidents and incidents, which were categorized under landing occurrences, showed significant parallels to the approach events and, as a matter of fact, most of the causal factors actually originated during the approach phase. Thus, including those events essentially provided this research project with a beneficial amount of data to permit an accurate statistical analysis. In addition, one more incident report that was labeled under the go-around phase also was included in the data collection. This minor modification of the research design was necessary to permit the inference needed to examine the hypothesis.

Data Collection

A data search was performed through the "Search Aviation Accident Reports" link on the FAA (2012) webpage, which opened a link to the NTSB (2012b) "Aviation Accident Reports." The presented data was reviewed, critiqued, and collected in reference to approach and landing accidents/incidents of commercial multi-crew airplanes in the U.S. NTSB (2012a) provided another search possibility and allowed for a custom selection of different criteria, which are displayed in Table 1.

An additional search was performed and focused on the frequency of international airlines, which were involved in CRM-related accidents and incidents within the U.S. The only two altered categories were "Operation" (Part 129: Foreign) and "Broad Phase of Flight" (All). Without a structured and standardized classification system, a quantification of trend-specific types of human errors would almost be impossible as only a descriptive summary of the reports would be achievable. Therefore, the Human Factors Analysis and Classification System (HFACS), as outlined in Appendix A, was used (Wiegmann & Shappell, 2003).

TABLE 1
Search criteria for the aviation accident database and synopses.

Accident/Incident Information	
Event Start Date	January 1, 2002
Event End Date	August 31, 2012
Country	United States
Investigation Type	All (Incident, Accident)
Aircraft	
Category	Airplane
Amateur Built	No
Operation	Part 121: Air Carrier
NTSB Status	
Report Status	All
Event Details	
Broad Phase of Flight	Approach, Go-Around, Landing

In total, 113 accidents and incidents were extracted for analysis. After identifying all the mishaps in the researched segments of flight, a categorization in regards to the probable causes was performed. More precisely, a critical assessment of the presented reports was conducted and allocated to the different error categories of the unsafe acts. Additionally, an investigation of the preconditions for unsafe acts, mainly in the CRM category of personal factors, was made (see Appendix A).

For the purpose of this research project, only the relevant parts of the HFACS framework will be illuminated in more detail. The unsafe acts category can be divided into two groups: errors and violations (see Appendix A). Generally, errors symbolize the unintentional mental and physical actions of individuals that fail to achieve their intended outcome. Violations, on the other hand, refer to the deliberate disregard of rules and regulations (Wiegmann & Shappell, 2003). However, the analysis of the collected data was restricted to the identification of the various errors. Those cases where the aircrews did not adhere to SOPs, for instance, were included in the decision errors.

Skill-based errors

In the context of aviation, skill-based errors are best explained as basic flying skill mistakes that occur without substantial deliberate thought. Usually, actions resulting from this type of error are especially vulnerable to failures of attention and/or memory. In addition, these errors occur in the execution of a routine, procedural task, training, or proficiency and end in an unsafe situation. Examples include: distraction, negative habit, task overload, misprioritizing, omitting checklist item or step in procedure, poor airmanship, inadequate use of flight controls, and breakdown of visual scan (Wiegmann & Shappell, 2003).

Decision error

This error form represents intentional behavior that continues as planned. The only difference is that the plan itself is inadequate or inappropriate for the given situation. Those "honest mistakes" are usually committed because the individuals did not have the correct knowledge or just simply made a poor choice. Examples include: wrong response to an emergency, exceeding ability, inadequate knowledge of systems/procedures, and inappropriate maneuver/procedure or problem solving (Wiegmann & Shappell, 2003).

Perceptual error

Typically, perceptual errors happen when the aircrew experiences either a degraded or unusual sensory input. In general, when the perceptions of the surroundings differ from reality, errors will occur. Examples include: misjudging distance/parameters, spatial disorientation, and visual illusion (Wiegmann & Shappell, 2003).

Labeling

Accidents or incidents were labeled as "management-related" when the determined probable cause, a contributing factor, or the analysis section of the official NTSB report mentioned any relevant findings about deficiencies in company regulations, procedures, or aircrew training.

Statistical Analysis

After scrutinizing the collected data, a statistical analysis of the outlined factors was conducted. A χ^2 test of independence in the form of a 2×2 contingency table was conducted to determine if there would be a statistically significant ($p < 0.05$) difference in the proportions of airline management-related versus non-airline management-related causes of accidents/incidents. This test was selected per the recommendation of the University of California, Los Angeles (UCLA) Institute for Digital Research and Education (IDRE, 2013) as the data was non-parametric and categorical in nature. As noted by McDonald (2009), "the chi-squared test of independence is used when you have two nominal variables, each with two or more possible values. A data set like this is often called an 'R × C table,' where R is the number of rows and C is the number of columns" (para. 3) and is appropriate when "comparing frequencies of one nominal variable for different values of a second nominal variable" (para 1).

Results

The collected data, a sum of 113 investigation reports that were extracted from the NTSB online database, incorporated three different phases of flight. The approach segment included a total of 41 (36 percent) accidents/incidents; the landing phase listed 71 (63 percent) plus the one (1 percent) event in the go-around segment. In regards to CRM, 57 (50 percent) accidents/incidents listed a CRM-related casual factor or included a similar commentary within the analysis section of the report. Those 57 occurrences could further be divided into 35 (61 percent)

Table 2
Data review and phase breakdown of CRM-related mishaps.

	Approach	Landing	Go-Around	Totals
Accidents	10 (29%)	25 (71%)	-	35 (61%)
Incidents	2 (9%)	19 (86%)	1 (5%)	22 (39%)

Note. Numbers in table are frequencies and percentages (parentheses) of CRM-related mishaps. The dash (-) indicates that data in this specific area could not be obtained.

accidents and 22 (39 percent) incidents. Table 2 illustrates a detailed breakdown of the mishaps per segment of flight for an enhanced review of the results.

After critical analysis of all the collected data, the three different error types (skill-based, decision, and perceptual) were allocated to the individual reports. In order to create a valid contingency table with the minimum value of five in each section, categories had to be combined. Perception and skill-related errors were combined due to their identified relationship in the literature. Table 3 indicates the reviewed data and illustrates the chosen categories as well.

The results of the statistical analysis found that there was no statistically significant difference in the proportions of accident type, $\chi^2(1) = 0.682$, $p = 0.41$, $d = .156$. Since $p > 0.05$, it was necessary to reject H_a and to accept H_0.

Limitations

In this case, not all of the NTSB accident and incident reports were full investigation reports with hundreds of pages. For some of the events there was only a short, but completed, report available. At times, it was not more than a factual summary with an official NTSB statement at the end. Consequently, those reports did not contain the desired detail on airline management procedures, training, and guidelines. In addition, information about training attendance or more specific details could not always be gathered. Yet the collected reports revealed enough data in order to execute a valid statistical analysis.

The actual results of the statistical analysis indicated a small effect size contrary to the planned medium effect size. As such, the *post hoc* power calculation indicated that the actual power did not meet the desired 0.80 level. Thus a potential explanation of the conducted χ^2 is that the sample size was not large enough to provide the necessary sensitivity to detect differences in proportions of accident types.

Discussion

Preconditions for Unsafe Acts

Whilst all of the categories in the preconditions for unsafe acts (see Appendix A) are considered critical and play a tremendous role in the investigation of an accident, this research project focused more on the personal factors in CRM, their operational application, and how this related to EM on final approach. Examples include lack of supervision, failure of leadership, misinterpretation of radio calls, poor communication, lack of assertiveness, lack of teamwork, and failure to conduct an adequate brief. The condition of the operator category also covers some very important states that can be of great impact in commencing an unsafe act by the aircrew. Examples include the lack of aptitude to fly, inadequate experience for complexity of situation, information overload, distraction, channelized attention, task saturation, overconfidence, stress, complacency, and loss of SA (Wiegmann & Shappell, 2003). All of these examples of preconditions for unsafe acts are paradigms for adverse mental states/limitations and require detection first in order to mitigate the outcome and prevent the occurrence of unsafe acts.

Good communication skills by flight crews are one of the core topics of CRM. Cockpit voice recorders give investigators insight into such communications after an accident has occurred; however, they do not provide a full understanding of all the activities on the flight deck, but they can supply the investigators with an idea on what happened prior to an accident and why (Nevile & Walker, 2005).

Table 3
Research results for a 2 × 2 contingency table.

	Airline Management-Related Factors	Non-Airline Management-Related Factors	Total
Skill-Based Errors Only	7 (4/3/−)	18 (3/15/−)	25 (7/18/−)
Non-Skill-Based Errors or Combination of Errors	6 (−/6/−)	26 (5/20/1)	32 (5/26/1)
Total	13 (4/9/−)	44 (8/35/1)	57 (12/44/1)

Note. The category "Non-Skill-Based Errors or Combination of Errors" includes decision and perceptual errors and/or a combination of two or more of the three error types. The values in parentheses reflect the different phases of flight (approach/landing/go-around). The dash (−) indicates that data in this specific area could not be obtained.

The research of Nevile and Walker (2005) not only concentrated on the instant of error itself; instead, they focused on the circumstance in which it occurred. Specific elements of interaction led them to believe that the way pilots communicate with each other can create a context for error. In their findings, Nevile and Walker (2005), found overlapping talk, lack of reply, and also unnecessary corrections from the pilot in command. In the end, in reference to their cited mishap, the flight crew did not work together in harmony. Independently, each of those findings may have been inconsequential, but collectively, they had a snowballing effect. Consequently, standardized communication on the flight deck is a necessity in attaining effective communication and ultimately effective crew performance on final approach for the purpose of decreasing accidents in this crucial phase of flight.

Attitudes and Human Behavior in Commercial Multi-Crew Cockpits

In commercial airline cockpits today, with their modern automation, pilots have to cautiously monitor the flight path and systems (FAA, 2004). The percentage of threats and errors increases especially during the approach-to-landing phase of flight (Helmreich et al., 2001). Therefore, actively crosschecking the other flight crewmember and his actions is needed or otherwise flight safety can be compromised (FAA, 2004). Several accident reports (e.g., NTSB, 2004, 2010, 2011) indicate valuable lessons of monitoring and challenging. Nevertheless, monitoring has to precede challenging in order to observe the situation and detect the deviation (Sumwalt, 1999).

The FO in the NTSB (2011) accident report undoubtedly showed monitoring initiative and even challenged the captain of the aircraft. Though, the large difference in experience between the two pilots, in combination with her weak assertiveness to enforce SOP adherence, most probably discouraged her challenging efforts toward the seasoned captain. On the other hand, the captain's deficiency in monitoring may have been influenced by fatigue, but company training was mentioned as a contributing factor as well.

The circumstances described in the NTSB (2004) accident report were somewhat different. Here, considerable lack of monitoring by the captain and the flight engineer were identified. Consequently, the unsafe acts that led to the accident were not detected and safety was compromised. Fatigue, high workload, and rushed procedures, no matter what, the errors were not detected or challenged. Therefore, the ineffective crew monitoring and crosschecking was literally the last line of defense that failed and did not prevent the accident from happening (FAA, 2004).

The NTSB (2010) revealed that the pilots were involved in non-pertinent conversations during all segments of flight, including those that are defined as critical by sterile cockpit rule. Besides the actual causal factors of this accident, the NTSB is concerned that neither pilot of the accident flight seemed hesitant to engage in non-pertinent conversations or demonstrated corrective behavior toward the other crewmember. Unfortunately, these facts leave room for interpretation that non-pertinent conversations among company pilots during critical phases of flight were not unusual.

Conclusion

Admitting to errors is an important element of EM. It assumes that events will not always turn out the way they were anticipated because humans will make errors. The perfect flight will most likely not be achievable, but striving for perfection will help to keep errors small and manageable. Effectively managing these errors is key to safe flying operations, thereby avoiding small errors from escalating to dangerous levels (Spare, 2006b). Managing errors can be accomplished best when crewmembers work together effectively. Successful multi-crew cockpit operations are a product of effective CRM training, which ought to be well thought-out and strategically targeted to the requirements of the individual air carrier and the surroundings in which they operate.

The FAA (2004) outlined CRM training and offers the required standards for commercial airlines. Then again, airlines usually design their own company SOPs for flight deck crewmembers. The FAA (2003) has been providing the elementary guidelines for those procedures. Still, many of the researched data indicate that, particularly in reference to effective communication and monitoring skills, the aviation industry has a lack of standardization in CRM training. Reoccurring similar causal factors in CRM-related accidents and incidents could still be identified, although CRM training evolved consistently (Salas, Wilson, Burke, & Wightman, 2006).

The FAA (2003, 2004) included valuable examples for setting the right priorities in reference to workload management. Now, it is the responsibility of the individual air carrier's management to incorporate those guidelines into their own CRM training programs and SOPs. By offering aircrews the best possible tools to apply proper CRM, only then is maximum crew performance attainable. Almost two decades ago, Besco et al. (1994) identified the necessity to improve flight crew training. However, the greatest obstacle in their analysis was cost. In general, airlines are very conscious about their budget and costs are high, probably too high to spend much time talking about low-probability events. As previously mentioned, the potential cost increase for air carriers, with a contemporary CRM training update for flight crews, would be negligible if compared to the monetary loss of an aircraft, not even considering the catastrophic outcome and subsequent publicity.

Helmreich et al. (2001) suggested, in order to decrease the amount of errors commenced on approach, appropriate TEM training is essential. Programs that aim for better aircrew performance levels can do such by confronting pilots with increased challenges to attain safe flying operations (Gunther & Tesmer, 2001). Flight crews need to continuously adjust the plan as they monitor, evaluate, anticipate, and consider contingencies. Most importantly, solid and dedicated preparation, planning, and execution are prerequisites for successful and effective crew performance, especially in go-around decisions to avoid ALAs (Spare, 2006a; NTSB, 2004, 2011). According to Sumwalt, Thomas, and Dismukes (2002), policy changes, training, and pilots following active monitoring concepts can considerably improve crew monitoring and challenging skills. One method to exercise those skills is through including deliberate errors during LOFT scenarios. In the end, enhancing flight crew monitoring skills can improve flight safety (Sumwalt, 1999).

Further scientific research is vital in order to evaluate the true impact of CRM training on flight safety. Key aspects for improving monitoring and challenging skills in effective EM are the air carrier's policies and procedures, especially during the high workload approach-to-landing segment of flight.

As already suggested by Spare (2006b), flight crews have to be mentally ready to initiate a go-around maneuver when flight safety dictates. That mental state has to supersede the different pressures to land the airplane as scheduled. Thus, a wide-ranging implementation of monitoring and challenging policies must be included in the air carrier's SOPs and training manuals. Air carrier management has to enforce improved and strategically targeted training to ensure their flight crews are adequately prepared for the next generation of modern aviation technology. Then again, it is crucial that flight crews develop proper EM skills and procedures. Error detection and recovery from errors should be reinforced in training (FAA, 2004) in order to mitigate flight safety occurrences. Effective CRM starts in initial training and is intensified by repetition and feedback. Therefore, EM must encompass a significant part of CRM training, while also being built in to the corporate culture and continuously being emphasized in every subsequent phase of training (FAA, 2004).

Clearly the importance of CRM and company guidance to encourage such practices is essential to the mitigation of pilot error accidents. The proper alignment of CRM and SOPs can give flight crews the optimum tools and environment to avoid falling prey to failures that could potentially lead to an accident. Several possible lessons can be gleaned from the findings of this study. Among CRM-related accidents and incidents, there is no significant difference in the percentages of occurrences based upon airline management procedures or compliance thereof and those that did not involve airline management issues. This indicates a favorable alignment of SOPs and CRM philosophies. In theory, if there were large numbers of CRM accidents in which management-related problems/errors were noted, there could be a disconnect between management and pilots in terms of procedures and compliance. There are larger numbers, albeit not statistically significant, among non-management-related accidents/incidents, particularly in the non-skill-based category. This may indicate that when there is compliance with CRM and management protocol, a lower likelihood of negative consequences exists. A key example would be the use of proper monitoring and processes during the approach and landing phase, which preserves error management in a critical phase of flight. Further research into these possible implications is necessary to confirm these suppositions. This study sought to identify differences between the management and non-management influences on CRM-related accidents and incidents. Whilst more investigation into this subject is required, this research was able to provide preliminary evidence of the positive effects of active CRM and airline management.

Suggestions for Future Research

Based on the findings of this study, the following recommendations are made for future studies:

1. Repetition of the current study with a larger sample size
2. A qualitative study of airline SOPs and CRM procedures to evaluate themes and alignments of goals, policies, training, and evaluation of these aspects
3. An evaluation of the adoption and use of CRM procedures internationally
4. An evaluation of recent approach and landing accident reports to identify breakdowns in CRM and/or SOP compliance or guidance

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Appendix A

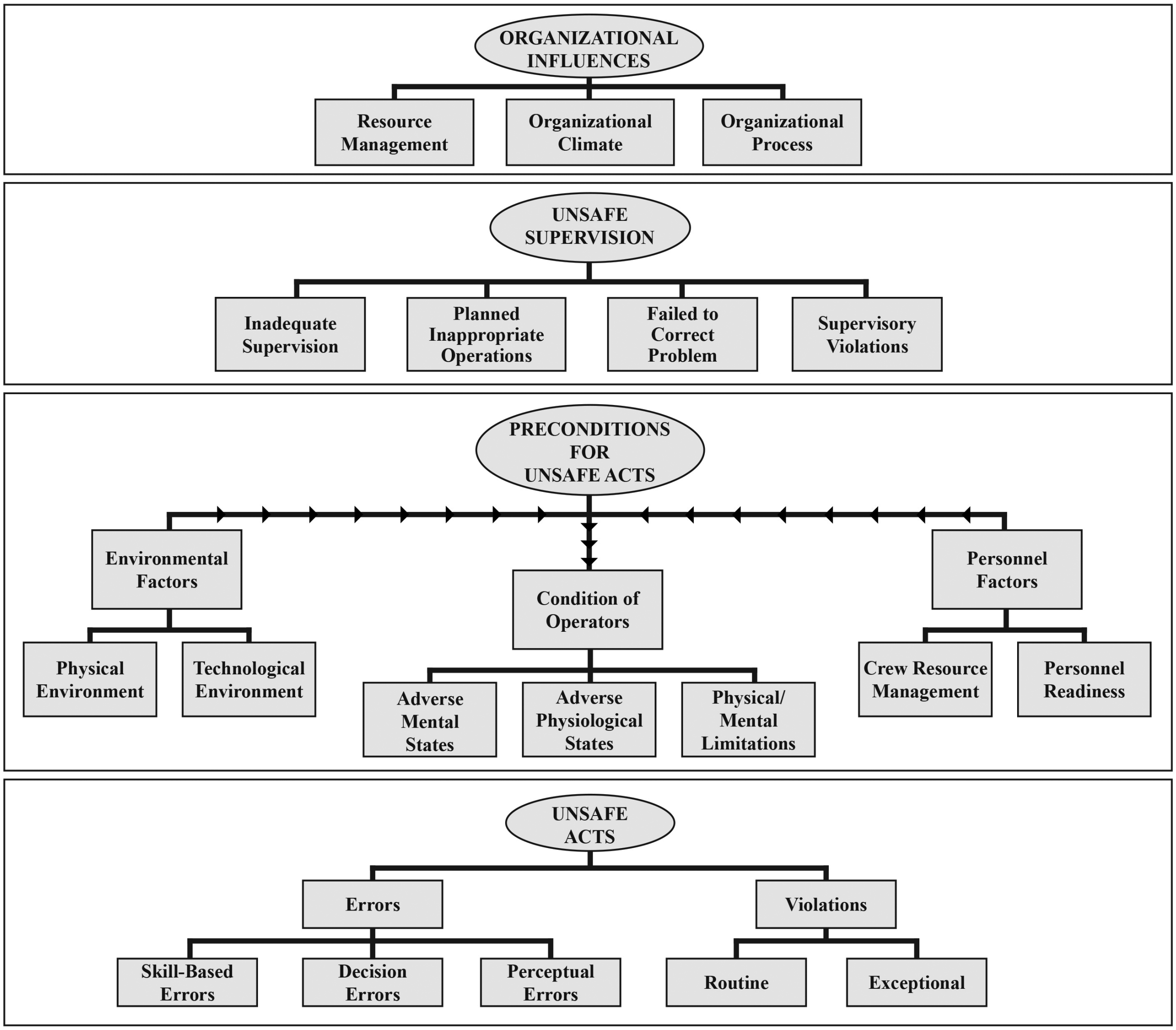

Figure 1. The Human Factors Analysis and Classification System (HFACS). Adapted from Wiegmann & Shappell, 2003.