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Risk - A Multi-Layered Approach

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Operational safety is a mandatory tangible and intangible element in the commercial airline industry. Air carriers must not only have a demonstrable safety record, they must also create a passenger feeling of being safe. Industry safety requires a multi-layered approach to identifying hazards and mitigating the associated risks. In order to emphasize this imperative, Congress requires operators that hold an air carrier certificate operate with the highest degree of safety. To ensure compliance, Congress promulgated Title 49 of the U.S. Code of Federal Regulations (CFR) § 44702 that requires that the Federal Aviation Administration (FAA) Administrator to “...consider the duty of an air carrier to provide service with the highest possible degree of safety in the public interest...” (Title 49 – TRANSPORTATION, Sec. 44702 - Issuance of certificates, 2006, p. 907) prior to the issuance of an air carrier certificate. In order to assure the highest level of safety in the air carrier industry, the FAA promulgated 14 CFR part 5 in 2015 that outlined, among other things, the four components of a Safety Management System (SMS) (FAA, 2020a). The FAA issued this regulation as a member state of the International Civil Aviation Organization (ICAO) to comply with directives embodied in Annex 19, Safety Management (ICAO, 2013). Additionally, the FAA revised its national policy regarding operator SMS on June 24, 2020 when it issued FAA Order 8000.369C (FAA, 2020b). This latest update emphasized the importance of SMS to industry safety, and it reinforced the “continuous improvement” (FAA, 2020b) of the four elements of the SMS: Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion.

The purpose of the Congressional approach to statutorily reinforce the philosophy of safety is multi-faceted. It requires operators to be accountable to passengers, employees, regulators, and to managers for the health and well being of the enterprise. The application of the SMS components is a structured method to protect assets, both human and materiel. Through the SMS decision process, financial asset allocation decisions are made in an efficient manner to apportion assets where safety and operational issues are shown to have the highest risk. Pareto, the Italian economist, analyzed the 80/20 phenomenon correctly when he determined that funds allocated to mitigate 20% of the hazards resulted in an 80% reduction in risk (Duszynski, 2020).

Common Definitions

The common definitions used in the SMS programs are listed in Table 1.

Table 1
Common Definitions

Term	Definition
Hazard	A condition that could foreseeably cause or contribute to an aircraft accident as defined in 49 CFR 830.2.
Risk	The composite of predicted severity and likelihood of the potential effect of a hazard.
Risk Control	A means to reduce or eliminate the effects of hazards.
Safety Assurance	Processes within the SMS that function systematically to ensure the performance and effectiveness of safety risk controls and that the organization meets or exceeds its safety objectives through the collection, analysis, and assessment of information.
Safety Management System	The formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk.
Safety Objective	A measurable goal or desirable outcome related to safety
Safety Performance	Realized or actual safety accomplishment relative to the organization's safety objectives.
Safety Policy	The certificate holder's documented commitment to safety, which defines its safety objectives and the accountabilities and responsibilities of its employees in regards to safety.
Safety Promotion	A combination of training and communication of safety information to support the implementation and operation of an SMS in an organization.
Safety Risk Management	A process within the SMS composed of describing the system, identifying the hazards, and analyzing, assessing and controlling risk.

Note. Adapted from (Federal Aviation Administration, 2020a, para. §5.5)

SMS

An operator or provider SMS program is “The formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for

the management of safety risk” (FAA, 2020a, para. §5.5). Figure 1 displays a concept diagram of SMS.

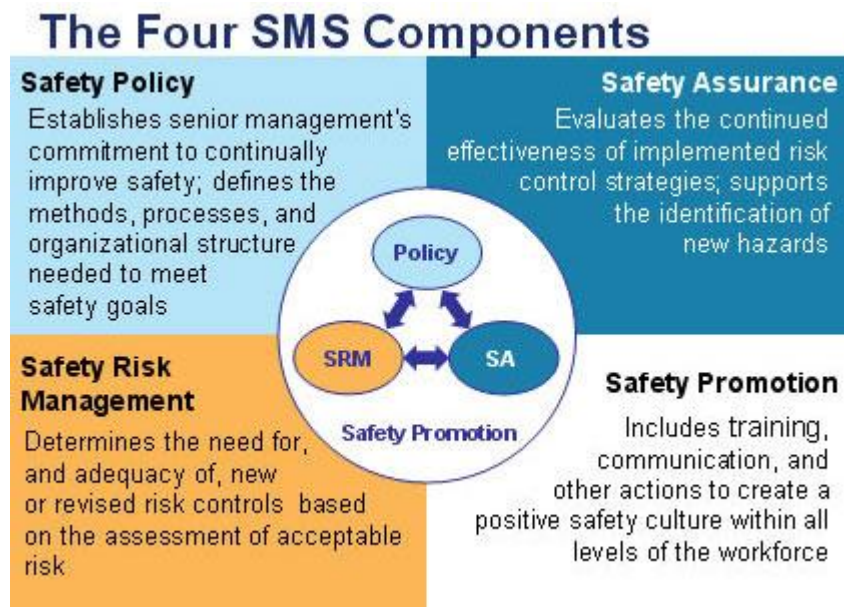


Figure 1. The Four SMS Components (FAA, 2017a, para. 3).

Safety Policy

The SMS order sets forth four foundational components of SMS; Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion (FAA, 2020b). Safety Policy is the centerpiece of the SMS program. It outlines the duties, responsibilities, and accountabilities of all employees necessary to document the organization’s commitment to safety. The Safety Policy requires the naming of an accountable executive who is the executive ultimately responsible for the success of the organization and for organizational safety (FAA, 2020a). In addition to setting managements’ and employees’ expectations and commitment to operate with the highest level of safety, the safety policy includes the operators’ safety response plan and establishes safety reporting systems to be used to identify safety issues throughout the company (FAA, 2020).

Safety Risk Management

The second component of SMS is Safety Risk Management that endeavors to establish a formalized program to identify hazards and to codify the subsequent risks the hazards present. In general, the FAA provides oversight and monitoring of the hazard analyses and risk management decisions the operator applies to ensure the highest level of safety (FAA, 2017b). Additionally, the FAA charges organizations with the responsibility to document whatever actions are taken to

mitigate risks and to establish a public-private communications path with the FAA to further enhance safety risk management.

Safety Assurance

The purpose of the Safety Assurance component is to ensure that the safety mitigations implemented based on the data collected during the risk management phase have the desired effect on safe operations (FAA, 2020b). This element of SMS incorporates the concepts of system analysis, hazard identification, safety risk analysis, risk assessment, risk control, and tracking and monitoring selected mitigations (FAA, 2017b). A continuous feedback loop provides up-to-date data for responsible managers to track the effectiveness of the selected risk mitigations. In this manner, managers are able to analyze mitigation effectiveness and modify the safety controls if the mitigations do not provide measurable target improvements in operational safety. Data analysis through audits, evaluations, and continuous monitoring through employee reporting systems contribute to the effectiveness of decisions implemented or modified by responsible managers (FAA, 2017b).

Safety Promotion

The Safety Promotion component is the information and training element for SMS. This component connects the training of safety systems to the communication of safety information to employees who support the overall SMS. Under the umbrella of the Safety Promotion component, the organization provides safety training to develop appropriate job category proficiencies in order to contribute to the overall operational safety. Responsible managers should use the Safety Promotion component to disseminate information to ensure an informed workforce and to create a positive safety culture at all strategic and tactical levels of the organization. This positive safety culture creates a trust in company policies and permeates all operational levels with shared goals and safety behaviors as well as responsibility and accountability for one's actions.

With the exception of Safety Risk Management, the three components of SMS are objective in nature. Safety Policy follows directly from an organization adhering to a philosophy of safety above profits. Safety Assurance protocols adhere to common statistical analysis and interpretation protocols to assure safety mitigations are effective. Safety Promotion methods utilize standard training and communication schema.

The Safety Risk Management component is inherently subjective. The FAA SMS order dissects the theoretical aspects of the Safety Risk Management (SRM) element of SMS. FAA Order 8000.369C (FAA, 2020b) and FAA Order 8040.4B (FAA, 2017b) purposely establish specific aspects of a SRM component the operator must develop and implement. It does not outline the various perspectives

and methodologies of hazard identification, risk determination, and risk mitigation. Once hazards are identified, the composite risk is computed in the risk matrix as a product of the predicted severity effects and the frequency/probability/likelihood of occurrence of the hazard. Risk is subjectively determined based on an individual's knowledge and experience level.

Risk

Risk Matrix

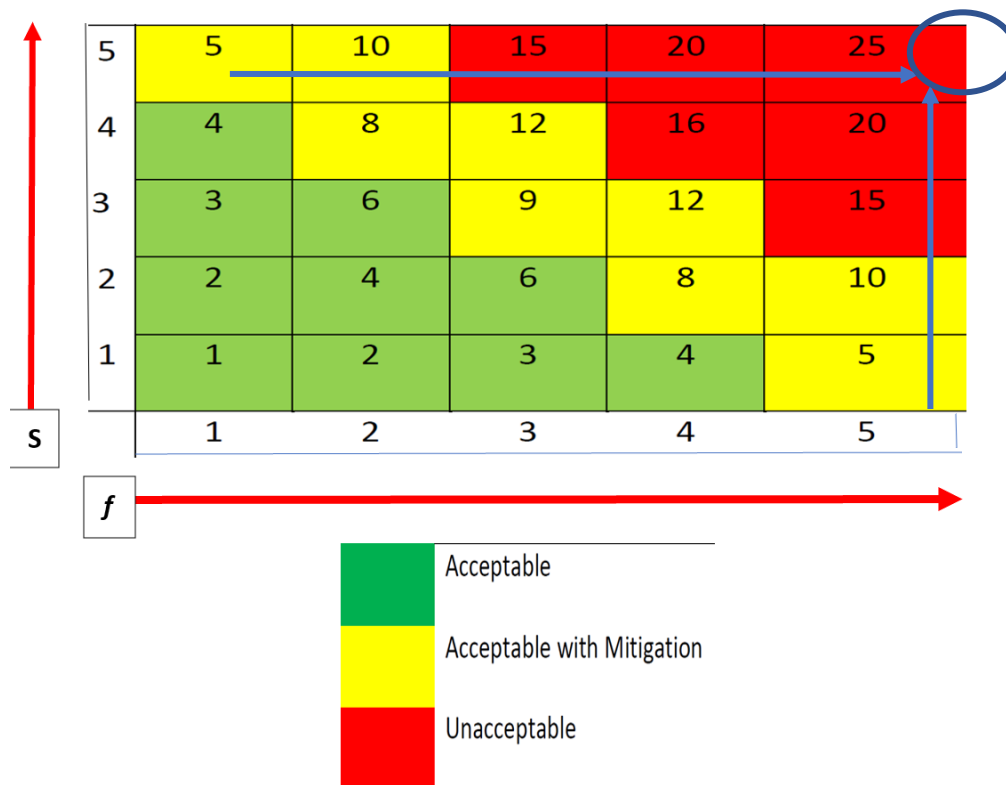
A risk matrix is a chart that represents the product of a hazard's severity and the likelihood, frequency, or probability of an occurrence precipitated by the hazard. Britton (2019a) characterized the risk matrix as "...the inter-industry safety standard as the primary tool used in risk evaluation" (para. 1). Common severity and /frequency/probability/likelihood definitions appear in Table 2.

Table 2.

Common Severity and Likelihood/Frequency/Probability Definitions

Severity	Severity Definition	Frequency/Probability/Likelihood Definition	Frequency
1	No safety effect	Extremely improbable-1 event/10 years	1
2	Minor-Slight reduction in safety	Unlikely to occur-1 event/5 years	2
3	Major-Significant reduction in safety margin	Unlikely but possible-1 event/year	3
4	Hazardous-Large reduction in safety margin	Likely to occur-more than 1 time/year	4
5	Catastrophic-Hull loss, fatality	Likely to occur-at least 1 time/month	5

An example of the common risk matrix appears in Figure 2.



S is Severity while **f** is frequency

S times **f** equals the risk number: $[(S \times f) = \text{Risk number}]$

Figure 2. Example Risk Matrix.

As seen in Figure 2, the quantification of risk based on a severity value of 5 and a frequency value of 5 results in a risk value of 25. Most charts use a 3-color schema where green is acceptable, yellow is acceptable with mitigations, and red is unacceptable. In the example, 25 falls in the red, unacceptable zone.

Strategic Risk

Strategic risk conceived of as predictive risk management involves the concept of forecasting potential hazardous events and assigning a risk value to them (Britton, 2019b). This process of risk identification is a critical management function because it precipitates the allocation of corporate personnel and financial assets. This first layer risk analysis occurs at an executive level with the purpose of “analyzing current operations to identify areas of potential concern in future, hypothetical situation [*sic*]” (Britton, 2017, para.1).

American Airlines Flight 331

On December 23, 2009, an American Airlines B737-823, operating under 14 CFR part 121 landed in Kingston, Jamaica and subsequently departed the end of the runway where it broke into three sections and came to rest. There were no fatalities although 14 passengers were seriously injured, and the aircraft was damaged beyond repair (Jamaica Civil Aviation Authority, 2009). Under the auspices of 14 CFR part 121.97, American Airlines was responsible to "...ensure a safe operation at that airport" (FAA, 2018). In the case of this accident, pertinent portions of the regulation included the requirement for American Airlines to evaluate runways, clearways, and stop ways as well as surface conditions, and instrument approach procedures at Kingston.

Based on a review of the accident report (Jamaica Civil Aviation Authority, 2009), the weather at the time of arrival was broken clouds at 1,400 feet with the winds from 320 degrees at 14 knots with moderate rain. The crew chose to execute the Instrument Landing System (ILS) approach to runway 12. This choice resulted in a direct tailwind of greater than 10 knots. The tower controller reported that the runway was wet. The crew crossed the runway threshold slightly high resulting in a touchdown 4,100 feet down the 8,911 foot runway.

The American Airlines risk analysis responsibility is manifested in pertinent part by the calculation of landing data available to the crew. The landing data presents required landing distance performance data based on the runway, the ambient density altitude, the aircraft gross weight, the flap setting, and the headwind or tailwind components present at touchdown. Using the American Airlines landing distance tabular data for 30 flaps, the accident investigators calculated a required landing distance with a 14 knot tailwind and fair to medium braking of 8,874 feet. The runway is 8,911 feet long leaving a margin of error of 37 feet. These figures included the 15% safety margin required by the FAA and are based on the assumption that the aircraft crosses the threshold at 50 feet above the runway (Jamaica Civil Aviation Authority, 2009).

American Airlines likely viewed these calculations as acceptable with mitigations. To mitigate the minimum margin for error on a wet runway with a tailwind, American recommended landing with 40 flaps. American also calculated landing performance using up to a 15 knot tailwind versus the usual limitation of 10 knots. Additionally, the calculations provided a 15% safety margin as discussed in FAA Advisory Circular 91-79A (FAA, 2014). American Airlines, as the operator, performed a strategic predictive risk analysis for operations at Kingston, Jamaica accounting for numerous landing performance circumstances as demonstrated by the extensive landing tabular data the company made available to the crew. The importance of the strategic, predictive risk analysis cannot be over emphasized. Although American changed the tailwind limitation for the B737 to 15 knots, there is no documentation that a risk analysis was completed by

American, Boeing, or the FAA (Jamaica Civil Aviation Authority, 2009). Additionally, American did not provide training to the flight crews for landing with tailwinds exceeding 10 knots. That landing with 15 knots of tailwind fell within the realm of acceptable, it proved to have quantifiable negative consequences (Jamaica Civil Aviation Authority, 2009).

Intermediate Tactical Risk

Another term for intermediate tactical risk might be proactive risk management. Normally, proactive risk management encompasses hazard identification through surveys and voluntary reporting (Britton, 2019b). For the practical use by a flight crew, this layer of risk analysis should be expanded to cover flight crew risk analysis during the preflight and enroute flight phases when considering potential approach and landing weather conditions. There are immediate risk analyses relevant to the preflight and enroute flight phases. However, the risk analyses required for the approach and landing phases will be the focus to illustrate intermediate tactical risk.

The concept of intermediate tactical risk or proactive risk is to consider plausible mitigating actions to perceived hazards before they occur. Mitigations are frequently determined based on crew training, knowledge, and experience combined with the application of company standard operating procedures (SOP) (Britton, 2019b). An orderly, formalized decision making or risk analysis process such as a RISK ASSESSMENT, the PAVE model, or the DECIDE model assists the pilot to weigh the risks of a planned operation.

Risk Assessment. Figure 3 provides an example of a RISK ASSESSMENT.

RISK ASSESSMENT

Pilot's Name _____ Flight From _____ To _____

SLEEP		HOW IS THE DAY GOING?	
1. Did not sleep well or less than 8 hours	2	1. Seems like one thing after another (late, making errors, out of step)	3
2. Slept well	0	2. Great day	0
HOW DO YOU FEEL?		IS THE FLIGHT	
1. Have a cold or ill	4	1. Day?	1
2. Feel great	0	2. Night?	3
3. Feel a bit off	2		
WEATHER AT TERMINATION		PLANNING	
1. Greater than 5 miles visibility and 3,000 feet ceilings	1	1. Rush to get off ground	3
2. At least 3 miles visibility and 1,000 feet ceilings, but less than 3,000 feet ceilings and 5 miles visibility	3	2. No hurry	1
3. IMC conditions	4	3. Used charts and computer to assist	0
		4. Used computer program for all planning	3
		Yes	0
		No	3
		5. Did you verify weight and balance?	0
		Yes	0
		No	3
		6. Did you evaluate performance?	0
		Yes	0
		No	3
		7. Do you brief your passengers on the ground and in flight?	0
		Yes	0
		No	2
	Column total		Column total

TOTAL SCORE _____

0 Not complex flight 10 Exercise caution 20 Area of concern 30 Endangerment

Figure 3. RISK ASSESSMENT retrieved from (FAA, 2016, p. 2-7).

This tool could have been used by the crew of American 331 to raise awareness of the potential risks associated with reduced visibility, low ceilings, high tailwinds, and a wet runway for the approach in Kingston. As a framework for discussion, the crew might have done a risk analysis and determined that a flaps 40 landing would have been the better option on a wet runway with a significant tailwind. The crew might have alternately considered landing into the wind on runway 30.

PAVE. The Pilot Handbook of Aeronautical Knowledge characterizes the value of the PAVE checklist as “Another way to mitigate risk is to perceive hazards” (FAA, 2016, p. 2-8). PAVE is a mnemonic that stands for Pilot, Aircraft, EnVironment, and External pressure. It is used to evaluate the readiness for flight of the components in the mnemonic. In the case of American 331, the crew (P) and the aircraft (A) met all of the requirements of the PAVE checklist. Additionally, the accident does not mention any indication that the crew was externally (i.e., the E in PAVE) pressured by the company to complete the flight to Kingston. The weather, the V in environment, required additional scrutiny and discussion of the potential hazards associated with arrival at an island destination during a moderate rain storm.

According to the accident investigation, the dispatcher provided extensive information regarding arrival weather, airfield notices to airmen (NOTAM), a primary alternate of Montego Bay, and a second alternate of Owen Roberts International Airport, Grand Cayman (Jamaica Civil Aviation Authority, 2009). According to the First Officer, the crew did not discuss the potential hazards and risks associated with arrival in Kingston during a moderate rainstorm which would have been appropriate at this preflight phase.

DECIDE. The DECIDE checklist is a hazard evaluation and risk determination structured decision process that can be used in the latter portion of the enroute phase or just prior to the top of descent (FAA, 2016). The (D) stands for the detection of a problem. The problem must first be perceived and then be evaluated by the crew using their collective training, knowledge, and experience. The first step is critical because correct analysis determines the subsequent steps taken to mitigate the risks associated with the perceived hazard. The (E) represents the estimate of the action required. The estimate includes elements of discipline, situational awareness, training, knowledge, and experience (FAA, 2016). Based on the perceived problem, the flight crew chooses a course (C) of action leading to a desired outcome. The flight crew is required to accomplish the actions (i.e., the second D represents the Do portion of the checklist) leading to the desired outcome. The second (E) portion establishes the feedback loop. Once the decision is made, the flight crew is responsible to continually evaluate the selected course of action to ensure that it results in the desired safe outcome (FAA, 2016).

In the case of American 331, the flight crew had numerous opportunities to evaluate the hazards of landing in the convective activity forecast for their arrival time. The accident report indicates that the crew completed a cursory briefing regarding the approach and landing. The First Officer considered the approach and landing under the reported conditions as “just another day at the office” (Jamaica Civil Aviation Authority, 2009, p. 21). Prior to the top of descent would have been an appropriate time to complete a landing performance evaluation and a discussion of the hazards to include a risk analysis of the various options available to the crew (Jamaica Civil Aviation Authority, 2009). The options included (a) completing a circle-to-land after the ILS approach in order to land into the wind; (b) executing an RNAV runway 30 approach in order to land into the wind; or (c) landing using flaps 40 with the tailwind. As the flying pilot, the Captain should have emphasized the importance of touching down in the touchdown zone to mitigate the hazardous effects of a tailwind and of a wet runway to the First Officer who was the pilot monitoring. If they were not going to touchdown in the touchdown zone, the Captain should have directed the First Officer to command a go-around and missed approach.

American Airlines provided tools to assist the crew in their decision making. The company recommended 40 flaps be used under the weather and

runway conditions encountered by the crew (Jamaica Civil Aviation Authority, 2009). The company recommended landing in the touchdown zone at the 800 to 1,500 foot point down the runway (Jamaica Civil Aviation Authority, 2009). Additionally, if the crew had perceived the problem correctly, they could have executed the RNAV 30 approach. Both the aircraft and the crew were RNAV qualified and the weather was above landing minimums for the RNAV approach at the time of arrival (Jamaica Civil Aviation Authority, 2009).

These decision making aides of a RISK ASSESSMENT, PAVE, and DECIDE mnemonics provide a structured multi-layered method to perceive the problem, perform an evaluation of a course of action, and evaluate the risks posed by hazards. The flight crew must then execute the course of action employing the risk mitigations and further determine via a feedback loop if their actions are achieving the desired results.

Immediate Tactical Risk

The concept of immediate risk or reactive risk management embodies the element of time criticality. Immediacy engenders “actions in response to hazard/risk occurrence” (Britton, 2019b, para. 1). In the case of frontline employees such as flight crews, it is their responsibility to take a course of action to mitigate the risk, avoid an accident, and minimize damages. For rapid decision making in dynamic circumstances, a simple, systematic approach to hazard identification and risk evaluation proves most effective (Federal Aviation Administration, 2016).

The 3P model of Perceive, Process, Perform is a very effective structured model to use in a very dynamic, time critical situation such as landing in adverse weather conditions. The perceive (P) element of the model is similar in function to the D in the DECIDE model. Perception of a problem by the flight crew requires excellent situational awareness. A correct perception of the problem precipitates an evaluation process represented by the second (P). The process (P) is an evaluation of the issue relative to flight safety and a determination of the hazard risk value (FAA, 2016). The third (P) represents perform. Once the flight crew perceives a problem and decides on a course of action, the flight crew must perform the required mitigating actions. Figure 4 represents the 3P model. As with previous models, this model also inherently establishes a continuous evaluation loop to determine whether the chosen course of action will result in the desired outcome.



Figure 4. The 3P Model (FAA, 2020c, p. 13-11).

In the case of American 331, it became very clear that the plan to land on runway 12 with a tailwind was not progressing as conceived when approximately 5 minutes prior to landing ATC advised the crew of the wet runway (Jamaica Civil Aviation Authority, 2009). The 3P model would have provided a structured risk analysis and decision making tool for this approach and landing. Through a continuous analysis of the circumstances, the crew should have perceived that the approach and landing phases were not proceeding as planned. They should have processed the hazardous circumstances of high tailwinds, wet runway, heavy rain, and a reduced flap setting for landing as a high risk threat to the safe conclusion of the flight (Jamaica Civil Aviation Authority, 2009). Once the crew processed the high risk to the desired safe outcome of the flight, it was imperative for the First Officer to command a go-around and for the Captain to perform the go-around (Jamaica Civil Aviation Authority, 2009). After the crew executed a successful go-around, the reinstatement of the 3P model would have been an appropriate crew action. The feedback loop should have been integral to the modification of the plan to either complete a safe approach and landing at Kingston or to divert and land at an alternate airport.

Conclusions

The various multi-layered strategic and tactical concepts of risk are important foundational elements in air carrier initial training, recurrent training, and Captain transition courses. The practical application of risk calculations using a risk assessment matrix, a pre-departure RISK ASSESSMENT, a PAVE or DECIDE structured analysis, or a 3P model should be discussed in initial and recurrent

ground schools as well as practiced in simulator scenarios and during initial operating experience qualification. The flight crew of American Airlines flight 331 had ample opportunity to include structured risk discussions as part of their crew briefings during the pre-flight, enroute, descent, approach and landing phases.

The risk matrix is the responsibility of the airline management team. According to the Jamaican Aviation Authority and based on the information available to the crew, the airline completed the usual and common station hazard identifications (Jamaica Civil Aviation Authority, 2009). American completed subsequent risk analyses resulting in a wide range of potential mitigating information and actions the crew could have used to achieve a safe outcome of the flight.

The flight crew was provided ample updates to the weather and to the destination airfield status. The accident report, based on information gleaned from flight crew member interviews, does indicate the crew took advantage of the information and discussed the options available to them to mitigate the hazardous conditions at the Kingston airport (Jamaica Civil Aviation Authority, 2009). The flight crew did appear to recognize (i.e., the D in the DECIDE checklist) the deteriorating conditions although they both appeared to have a common mental model of the weather conditions at Kingston that engendered a complacent attitude. If the flight crew had followed the recognition of the conditions with the remainder of the DECIDE structured checklist, the discussion might have provided an excellent format to deliberate various aircraft approach procedures and landing configurations appropriate for the different environmental conditions the crew might encounter upon arrival. Using a structured risk discussion such as the DECIDE mnemonic, the flight crew might have improved their situational awareness and their sense of urgency and not have perceived that "...the weather was not abnormal and it was 'just another day at the office'" (Jamaica Civil Aviation Authority, 2009, p. 21).

It is important to match the risk analysis with the phase of flight. For example, the PAVE or DECIDE checklists are not applicable in a rapidly changing environment experienced while landing in moderate rain (Jamaica Civil Aviation Authority, 2009). The Jamaica Civil Aviation Authority accident report (2009) stated that after the flight crew reported on the tower frequency, "The CVR contained no discussion between the two flight crews [the two pilots] about the increased tailwind, the reported rain shower activity, the runway conditions or calculation of landing distance" (p. 26). Under the circumstances, the 3P risk discussion should have led the crew to the least risk safe outcome that was to execute a go-around and missed approach. After the successful missed approach the crew would have had ample time and opportunity to use the DECIDE or 3P structured analyses to determine the next course of action.

Determining a flight crew action at its base level is a risk assessment. It is an imperative that the flight crew members use their collective training, knowledge, and experience to apply the appropriate decision making tool for the conditions and phase of flight in a multi-layered approach to ensure the safety of passengers and crew members. Under the dynamic environmental circumstances involved with landing in conditions experienced by the American Airlines 331 flight crew, the application of a suitably formalized, structured risk evaluation tool would have facilitated a risk informed strategy to effect a safe outcome.

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