MAKING THE GO, NO-GO DECISION BASED ON NON-TRADITIONAL WEATHER PLANNING INFORMATION: THE CHALLENGE OF MEASURING THE IMPACTS OF NEW TECHNOLOGIES ON PILOT'S WEATHER RELATED DECISION MAKING IN GENERAL AVIATION

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ABSTRACT

This paper explores contemporary issues regarding the challenges of quantifying improved decision making and situational awareness as it is applied to emerging tools in aviation weather information dissemination. The authors explore the phenomena of increased/improved pilot decision making due to additional visual representation of visual weather data. General concepts such as past and present flight planning tools and procedures are discussed. Additionally, the authors explore the Federal Aviation Administration's (FAA) Alaskan Weather Camera program as a potential case study for future exploration of these concepts. A pilot survey tool was created and administered to a small test population as a part of an undergraduate Aviation Psychology course assignment. Preliminary findings and suggestions for future research are presented.

Keywords: human factors, aviation psychology, undergraduate pilot study, general aviation

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1. INTRODUCTION

As weather related technology becomes more and more readily available to the average general aviation (GA) pilot, users, operators and providers will need to ask the question of whether or not more data equals more information that can be interpreted and used appropriately. In short, is the pilot's situational awareness (SA) affected by the new information and are better, more informed decisions being made? Researchers will need to determine whether or not the new information has an additional cognitive value. In other words, one needs to identify the measure and articulate how pilot decision making is improved.

Approximately a decade ago in a critical review of the concept of SA, Endsley (2000) identified SA in weather forecasting as sub-domain of SA that was emerging in the literature. This paper will focus on the Task or System Factors associated with SA of weather phenomena in the flight planning stage. The addition of non-traditional sources of weather data through remote visual aids and their ability to enhance the pilot's ability to make an improved go or no-go decision will be explored and a pilot study to test its effectiveness will be proposed.

One of the leading causes of fatal accidents in the aviation industry over the past two decades has been poor decisions made by pilots in deteriorating weather (FAA, 2013). These poor decisions are caused by underlying psychological factors. Over the last 20 years, there has been introduction of safety related initiatives as general aviation accidents involves pilot's decision to navigate in inclement weather conditions which has created a need for research efforts to analyse and develop interventions aimed at mitigating the incidence of GA accidents. To satisfy this need, researchers have examined aspects of visual flight rules into instrument metrological conditions accidents and have come up with factors that might assist in reducing the degree of associated fatalities but these interventions have proved to be limited by lack of theoretical framework.

While Visual Flight Rules (VFR) flight into IMC accounts for about 4% of all GA crashes, they comprise 19% of all GA fatalities. To understand the cause and consequences of the decision of a pilot to fly VFR into Instrument Meteorological Conditions (IMC), it is important to explore the various stages of decision making along with factors that affect these processes.

Visual flight rules are a set of aviation regulations under which a pilot may operate an aircraft independently if weather conditions allow the pilot to visually control the aircraft attitude, navigate and maintain separation from obstacles like terrain and other aircraft. Although the requirements vary with airspace and altitude, generally speaking, conditions of more than 3 statute miles visibility and cloud ceilings greater than 1000 feet meet VFR minima. A pilot flying under these rules is required to remain clear of clouds and maintain a specified flight visibility based on the classification of airspace they are operating in. The pilot is also responsible for avoiding aircraft and other obstructions. In accidents in which VFR flight into IMC was a probable cause, accidents were attributed to flight crew, poor weather information, pilot error, and failure to make good decision making. In order to reduce these accidents the FAA has developed several training programs to look into cognitive and affective components of pilot decision making (FAA 2, 2013).

Successful pilot judgment and decision making is affected by motivational and cognitive components. Cognitive components are the process by which pilots establish and evaluate alternatives in a decision making situation. This involves the pilot depending on ability to sense, store, retrieve and integrate information. The motivational component involves gains and losses associated with decision outcomes, social and personal pressures.

Causes of VFR into IMC include a variety of cognitive factors like situation assessment and risk perception as well as affective factors. It also includes motivation and decision framing combined with biases and heuristics. A solution to improve decision making is found through cognitive aspects of training, displays that make it easy to detect and integrate cues, and also tools to assess and formulate courses for action (Madhavan, 2006).

2. TASK OR SYSTEM FACTORS AFFECTING SA AND DECISION MAKING IN WEATHER FORECASTING FOR GA PILOTS

Traditional sources of aviation weather products available to GA pilots are numerous. Prior to the 1960s, pilots typically planned flights with Flight Service Station (FSS) personnel face to face. Telephone information briefings (TIBS) became available in the 1970s followed an online system in place today called the Direct User Access Terminal (DUATS) which provides pilots with a cadre of printed routine weather reports (METARs), area forecasts (FA), and terminal area forecasts (TAFs). Throughout the stages of information delivery from in person to at your fingertips, the types of information that can be shared their delivery systems also improved (NTSB, 2001. Pp 10-11).

The National Weather Service (NWS) improved upon Doppler radar and provided pilots with the next generation of radar (NEXGEN) that provided users with information on precipitation and wind(s) aloft.

Today, pilots typically begin their flight planning days in advance, watching frontal movements and tracking the position of high and low pressure systems. Depending on the skill, experience or certification limitations of the pilot, early decisions to cancel or reschedule a planned flight can occur in this early stage. Pilots can obtain outlook briefings from automated or over the phone briefings provided by DUATS or Flight Service Stations (respectively). Outlook briefings provide pilots with critical flight planning weather information trips planned more than 6 hours prior to initiating the flight. Within that 6 hour window, pilots request a standard weather briefing where they will need to translate, sort through and analyse a multitude of textual and graphical weather data that is both real-time in nature as well as predictive.

Pilots attempt to gain a preliminary understanding of the *state of the environment* (Endsley, 2000. page 3). This then affects situation awareness which is broken down into to three separate levels, Perception (level 1), Comprehension (level 2), and Projection (level 3). Situational awareness, in Endsley's model, drives direction and action.

In level 1, pilots form a perception of the cues being received from the external environment. Seventy six percent (76%) of situational awareness errors committed by pilots can attribute to difficulty with perceiving information incorrectly (Jones & Endsley, 1996).

In Level 2, Comprehension, Endsley (2000. Pp. 3-4) describes how pilots integrate the incoming data with other pieces of information and determine their relevance. Endsley reported that 20% of situation awareness errors were due to comprehension of the value of the information. He stated that individuals must consider both the subjective interpretation (awareness) and the objective significance (situation).

The final level (3) in situational awareness in Endsley's Dynamic Decision Making Model (1995) is Projection. Projection is the phase of situational awareness where pilots are able to use the information gathered to make future predictions. Aviation experts use projection to anticipate future conditions based on information from current sources.

Endsley identifies two temporal aspects of situational awareness that affect pilot cognition when interpreting weather information. One, how much time and space are available to process the information? Two, at what rate does the information change? These two aspects affect one's ability to accurately form a sense of self-awareness that is timely. SA is the precursor to the decision making process. However, Endsley points out that, "Good situation awareness should increase the probability of good decisions and good performance, but does not guarantee it" (2000. Pg. 18). Pilots require analytical skills and intensive training as a guide to help them focus on very important tasks such as pre-flight weather planning (Hunter, Martinussen & Wiggins, 2003).

3. TECHNOLOGY

A great way to mitigate human error in incidents would be to design the human out the problem through the use of emerging technologies that assist in decision making. Allowing automation reduces the workload on flight crew. Some of the downfalls would be over trusting automation or not trusting the system at all. For these flaws there must be a need to adequately train pilots in the use of automation (Lincoln, 2012).

4. VARIABLES INFLUENCING DECISION MAKING IN WEATHER RELATED DECISION MAKING

Pilots have been known to trust weather information they can directly observe more than sensor-based information that is digitally displayed (Latorella, K. A., & Chamberlain, J. P., 2001). Findings of a National Transportation Safety Board (NTSB) study in weather related decision making found that the following variables contributed significantly to flight outcomes: 1) age at time of accident, 2) age at first certificate, 3) highest certification, 4) instrument rating, 5) practical test cumulative pass rate, 6) accident/incident history, 7) planned length of flight, 8) purpose of flight, and 9) aircraft ownership (NTSB, 2001).

The Safety Board recommended that the FAA add a specific requirement for all pilots who do not receive weather-related recurrent training, that the biennial flight review include recognition of critical weather situations from the ground and in flight, and the procurement and use of aeronautical weather reports and forecasts. Among other findings, the study determined that:

a. Age of initial flight training determines risk (less risk for pilots who begin their training earlier in life).
b. Weather-related knowledge and skills need continual maintenance.
c. General aviation pilots routinely consult alternative sources of aviation weather to obtain information that is not currently available from a standard weather briefing.

Two recommendations for the FAA by the NTSB (2001, p. 48) included:

a. Determine optimal information presentation methods and delivery systems for flight service station weather information briefings, including the possibility of supplementing or replacing some portions of the current standard weather briefing with graphical data. (A-05-028)

b. Revise guidance materials associated with pilot weather briefings to include guidance for pilots in the use of Internet, satellite, and other data sources for obtaining weather information suitable for meeting the intent of 14 Code of Federal Regulations Part 91.103 and subsequently inform the aviation community about this change. (A-05-029)

Goh and Wiegmann (2001. pp. 359-360) point out that, although weather related accidents between 1990 and 1997 only accounted for a small portion of GA accidents, 2.5% of accidents accounted for approximately 11% of the fatalities. Approximately 22% of accidents occur due to diagnostic error. Additionally, the study found a clear difference between novice and expert performance. Goh and Wiegmann point out that pilots that frame their decision to divert as a loss (loss of fuel, time, etc.), they may tend to choose risky behaviours and choose to fly or continue to fly in poor or deteriorating weather. Framing decisions based on the concepts of gains and losses is articulated by Kahneman & Tversky's (1982) Prospect Theory. In Goh and Weigmann's experiment, they found that pilots were more likely to proceed into hazardous weather if they perceived that weather variables were less likely to be causal factors in aviation accidents.

Wiegmann, Goh & O'Hare (2002) conducted a study assessing the impact of flight experience on pilot deviation decisions in adverse weather. Their results indicated that novice pilots were more likely to continue into poor weather conditions more often and for more time than their more experienced counterparts. This decision is attributed to poor situational assessment skills of the less experienced pilots. A previous study conducted by the FAA (Driskell, et al., 1997) found that one can measure pilot's comfort policies in terms of emphasis on variables such as ceiling and visibility, and how they prioritize weather conditions.

Human information process is classified into three sequential categories: information acquisition, situation assessment, and choice of action. In this stage the pilot seeks cues from the environment and performance is primarily driven by attention, concentration and perception. Decision making and the choice of action is influenced by information stored in working memory and long term memory. Decision at the stages is most often affected by the overconfidence bias and the availability heuristic.

Pilots often engage in VFR into IMC as a result of failing to properly assess the latent hazards or conditions. Madhavan and Lacson (2006) found that 22% of accidents were due to human error resulted primarily from diagnostic errors. These diagnostic errors were more serious than aircraft handling (Air Traffic control) errors.

5. SAFETY METRICS

Safety performance measures are used as indicators for stakeholders to monitor any change in the system against established goals and objectives providing key trend information. Common safety performance measures are accident/incident rates, response times, and public/user perceptions. The US National Highway Administration (NHWA) , in its 2009 document on safety measures for transportation highlights that safety measures can provide, "….feedback to promote ongoing improvement of business processes as they relate to supporting safety strategies" (Pg.2). Sources of safety metrics include:

1. Core – Recorded accidents, incidents or safety related events.
2. Behavioural – Observational data from survey.
3. Activity Measure – Data collected during a specified performance period (e.g. Grant activity reporting).

The National Transportation Safety Board (NTSB, 2001) found that general aviation (GA) pilots routinely consult alternative sources of aviation weather to obtain information that is not currently available from a standard weather briefing. They determined that optimal information presentation methods and delivery systems for flight service station weather information briefings, include the possibility of supplementing or replacing some portions of the current standard weather briefing with graphical data. They suggested that the FAA revise guidance materials associated with pilot weather briefings to include guidance for pilots in the use of Internet, satellite, and other data sources for obtaining weather information suitable for meeting the intent of 14 Code of Federal Regulations Part 91.103 and subsequently inform the aviation community about this change.

6. STRATEGIC DATA COLLECTION PLAN FOR METRICS

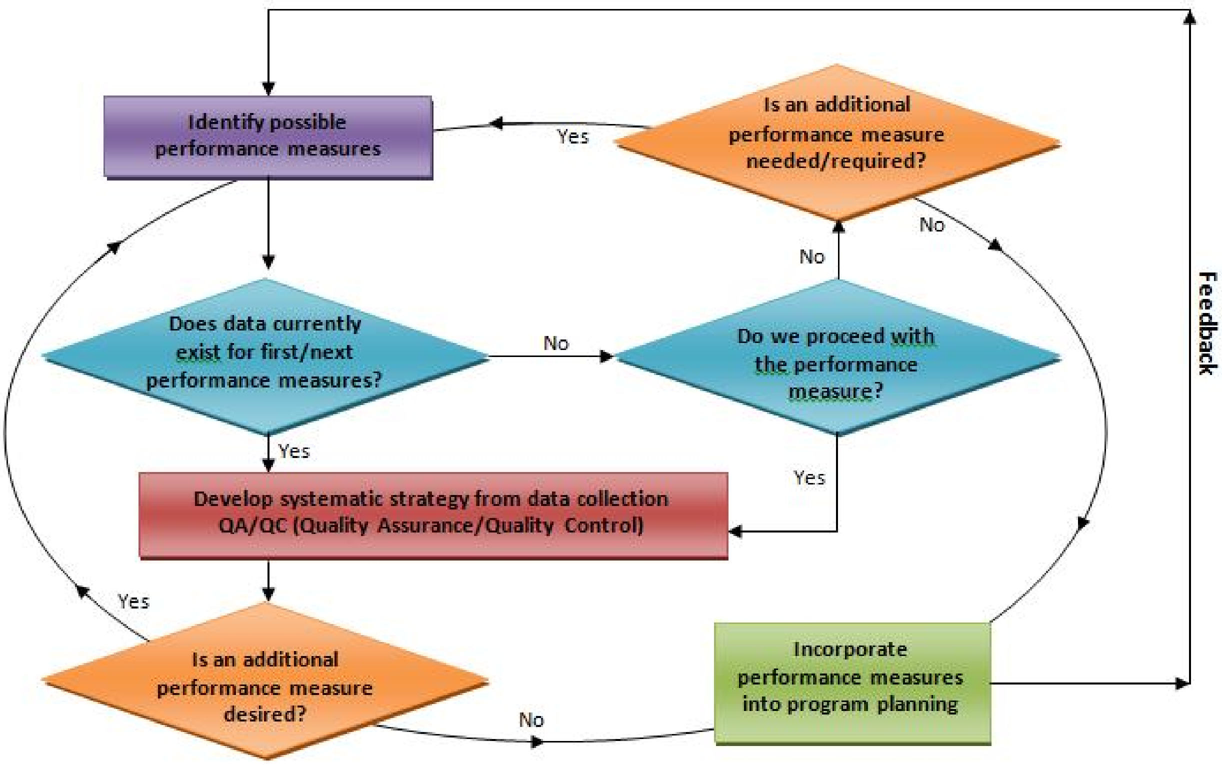
Metric identification, selection and use requires a plan. The following should be considered when choosing a metric:

* **Timeliness-** Can the data custodian produce reports and data in a timely manner to inform the performance measure process?

* **Accuracy**- How do you ensure that the data is accurate when collected initially and when received in the final desired electronic format?
* **Completeness**- What steps are you taking to ensure that all the data needed for the analysis are accurately represented? Are all factors included? Will the data account to a better understanding of physical or behavioural variables?
* **Uniformity/Consistency**- Do the databases you are utilizing have uniform codes and identifiers?
* **Integration**- Is one common database used at all levels? Ideally, this is the case.
* **Forecastability**- Is it difficult to predict future conditions using the measure given existing forecasting tools?
* **Accessibility**- How accessible is the data to those who will be conducting the analysis?

If not internal, describe the process of requesting the data and any time constraints. Herbel et al. (2009) developed a Safety Performance Planning Process (Figure 1) for identifying and utilizing performance measures. This process is used to determine whether or not additional metrics are required to measure the desired outcome.

Figure 1: Safety Performance Planning Process



Source: Adapted from Herbel et al. (2009)

7. CASE STUDY

The Alaskan Weather Camera Program is a good example of using emergent technologies to supplement the cadre of decision making tools available to general aviation pilots in making weather related go and no-go decisions. The program's mission is to improve Safety and Efficiency by providing near real-time images to aviation users. Its goal is to reduce weather related aviation accidents and improve operator efficiencies by reducing fuel and other operations costs. Its method utilizes images are made available to the public via the FAA Aviation Weather Camera Website (http://avcams.faa.gov/). The program consists of an array of weather stations and web cameras strategically placed throughout the state of Alaska aimed at providing general aviation pilots with supplemental weather data in locales and regions critical to flight safety where weather is more difficult to forecast.

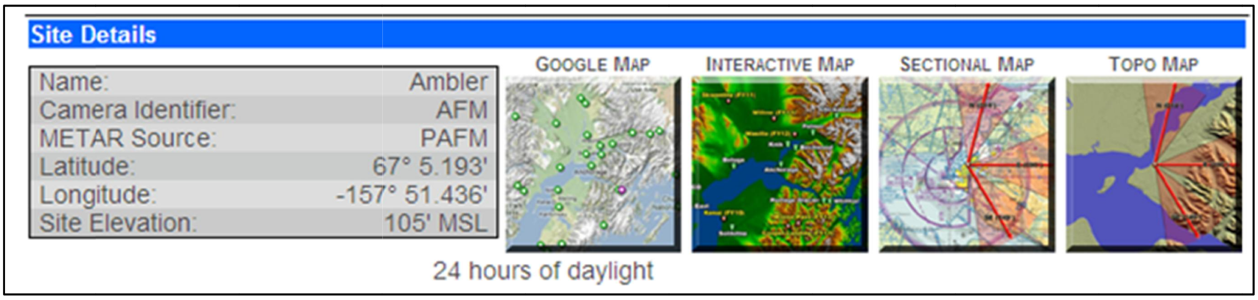
Figure 2: FAA Aviation Weather Camera Station

Source: Retrieved from www.parsons.com/projects/Pages/faa-tssc-iv.aspx

Increased safety in the form of increased pilot decision making was among one of the goals of the program, along with reduction in wasted fuel as a result of aborted flights due to un-forecasted deterioration of weather conditions.

Using the web site, pilots are able to locate the area of interest (flight path) and access real-time visual weather depictions.

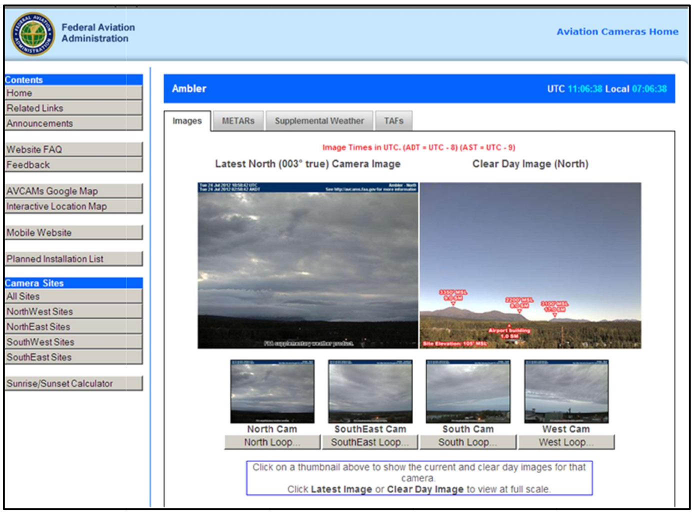
Figure 3: Weather Station Site Details



Source: Retrieved from http://avcams.faa.gov/index.php

After locating the desired site, pilots are able to compare the existing visual conditions with clear weather conditions to make an educated estimate of inflight visibility and cloud ceiling conditions.

Figure 4: Real Weather Versus Clear Day Comparison



Source: Retrieved from http://avcams.faa.gov/index.php.

8. PILOT STUDY DEVELOPMENT AND RESULTS

In an attempt to initially study the impact of additional visual data provided to pilots (via the Weather Camera System) on pilot's decision making, an undergraduate class studying Aviation Psychology developed a preliminary survey measuring pilot decision making for a fictional flight in the Alaska Region using real-world data. Students developed a preliminary pilot survey Developed a consent form Received Institutional Review Board (IRB) approval to meet exempt status and conduct the survey on campus Administered survey to freshman flight students currently enrolled in their second semester. Survey participants were first asked to make a decision to continue flight based solely on textual data provided by the FAA and National Weather Service.

Figure 5: Textual Weather Data

QUESTIONNAIRE

METAR text:	**PAFM 241056Z AUTO 19003KT 10SM OVC085 12/11 A2992 RMK AO1 PNO**
Conditions at:	PAFM (AMBLER , AK, US) observed 1056 UTC 24 July 2012
Temperature:	12.0°C (54°F)
Dewpoint:	11.0°C (52°F) [RH = 94%]
Pressure (altimeter):	29.92 inches Hg (1013.3 mb)
Winds:	from the S (190 degrees) at 3 MPH (3 knots; 1.6 m/s)
Visibility:	10 or more miles (16+ km)
Ceiling:	8500 feet AGL
Clouds:	overcast cloud deck at 8500 feet AGL
Weather:	automated observation with no human augmentation; there may or may not be significant weather present at this time

FIGURE 1. METAR 1056Z

METAR text:	**PAFM 241236Z AUTO 00000KT 10SM OVC085 11/09 A2994 RMK AO1 PNO**
Conditions at:	PAFM (AMBLER , AK, US) observed 1236 UTC 24 July 2012
Temperature:	11.0°C (52°F)
Dewpoint:	9.0°C (48°F) [RH = 87%]
Pressure (altimeter):	29.94 inches Hg (1014.0 mb)
Winds:	calm
Visibility:	10 or more miles (16+ km)
Ceiling:	8500 feet AGL
Clouds:	overcast cloud deck at 8500 feet AGL
Weather:	automated observation with no human augmentation; there may or may not be significant weather present at this time

FIGURE 2. METAR 1236Z

Source: Retrieved from http://avcams.faa.gov/index.php

After making the decision, they were given the supplemental weather data provided by the Weather Camera system.

Figure 6: Sample Progressive Weather Picture with Baseline Image

Source: Retrieved from http://avcams.faa.gov/index.php

Then, a series of questions were given to the students. A sample of the questions developed by the students appears in Figure 7 below.

Figure 7: Sample Survey Questions

1. Given the two meteorological observations from the METARS in figures 1 & 2 (from 1056Z and 1236Z), how would you define the weather at Ambler, AK?

a. Improving (getting better)
b. Slightly improving
c. Little to no change
d. Deteriorating (getting worse) slightly
e. Deteriorating

2. Based on the textual data in the Ambler METAR, if planning a Visual Flight Rules (VFR flight) cross-country flight through the Ambler, AK area which of the following would best describe your decision making process?

a. The weather is deteriorating (getting worse) and I would choose not to continue to plan this flight and stay home.
b. The weather indicates no changes in the last hour. With 10 miles visibility and a ceiling of 8500', I will continue planning for a flight through Amber.
c. The METAR weather information does not affect my decision making process when it comes to planning.

3. Based on the information available for Ambler, AK given in the METAR, a VFR flight through this area would be a:

a. Go (The weather is good for VFR, continue to plan on making the trip).
b. No-Go (The weather is marginal VFR or IFR, discontinue planning on making the trip).

Students' responses were analysed to determine whether or not the addition of the visual weather information had an impact on their *go, no-go* decision making process.

9. PRELIMINARY RESULTS

The following are results from the small pilot study conducted with undergraduate pilots in an aviation science course.

Question 1

Given the two meteorological observations from the METARS in figures 1 & 2 (from 1056Z and 1236Z), how would you define the weather at Ambler, AK?

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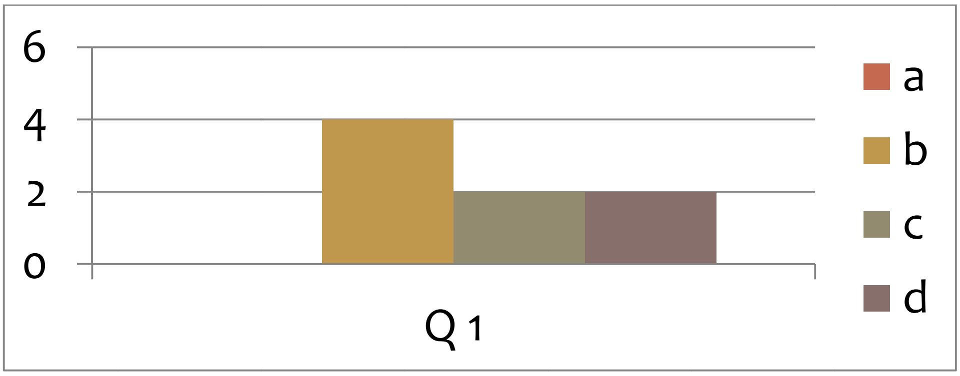
b. Slightly improving
c. Little to no change
d. Deteriorating (getting worse) slightly
e. Deteriorating

Figure 8: Question 1 Responses



Question 2

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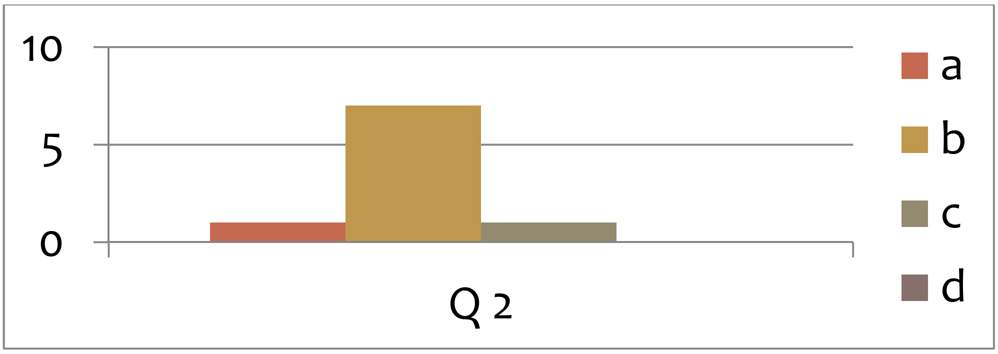
c. The METAR weather information does not affect my decision making process when it comes to planning.

Figure 9: Question 2 Responses

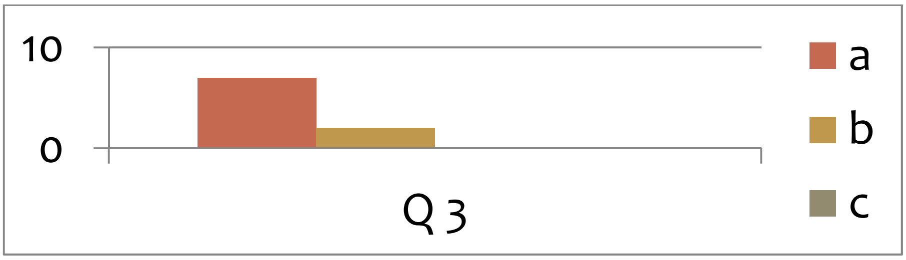


Question 3

Based on the information available for Ambler, AK given in the METAR, a VFR flight through this area would be a:

a. a. Go (The weather is good for VFR, continue to plan on making the trip).
b. No-Go (The weather is marginal VFR or IFR, discontinue planning on making the trip).

Figure 10: Question 3 Responses

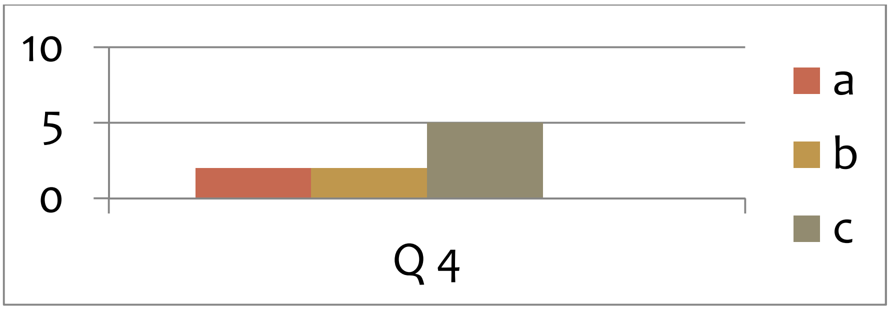


Question 4

Compared to the textual METAR data, which of the following best describes the relationship between the weather reported in the METAR data for Ambler and the visual weather image depicted by the camera at Ambler?

a. The same (No difference).
b. Slightly different (Not really significant).
c. Significantly different.

Figure 11: Question 4 Responses

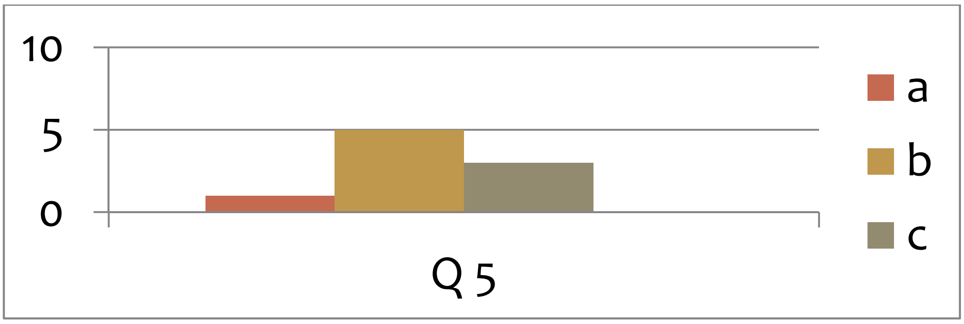


Question 5

Based on the series of visual weather images for Ambler when compared to the clear day image, which best describes your impression:

a. The cloud ceiling height and visibility based on the visual weather at Ambler was better than reported in the METAR.
b. The cloud ceiling height and visibility based on the visual weather at Ambler was the same as reported in the METAR.
c. The cloud ceiling height and visibility based on the visual weather at Ambler is worse than the reported in the METAR

Figure 12: Question 5 Responses

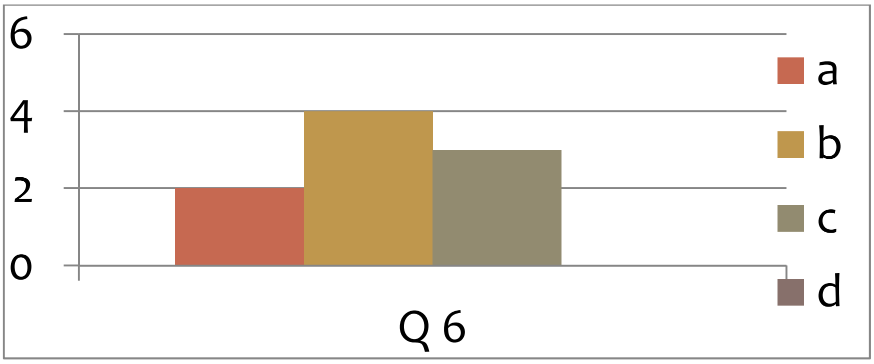


Question 6

Please choose which of the following best describes the impact of the additional visual weather information for Ambler on your flight planning decision making process to continue the flight (Go) or discontinue the flight (No-Go):

a. No impact on go, no-go decision
b. Limited impact on go, no-go decision
c. Moderate impact on go, no-go decision
d. Significant impact on go, no-go decision

Figure 13: Question 6 Responses



More than 50 % of the participants initially surveyed indicated that the weather in the textual weather report varied significantly from that in the visual weather camera data. When asked whether or not the additional information had any (scale varied from limited, moderate, significant) impact on their go or no-go decision, 77% indicated that it had some impact, and only 23% of the respondents indicated that it had no effect on their decision making. Based on the initial pilot survey activity, the students determined that additional research was warranted. Feedback from survey participants will be used to inform future focus groups to revise the survey instrument to address validity issues.

10. LIMITATIONS

These findings are only preliminary and within a classroom environment. The survey instrument is continuing to be refined and developed further into an electronic survey tool that will be deployed to a larger population to ensure greater validity and generalization to larger populations.

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