

GRAPHICAL ENHANCEMENTS TO THE EXECUTIVE INFORMATION SYSTEM (EIS) FOR THE AVIATION SYSTEM RISK MODEL (ASRM)

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KEYWORDS

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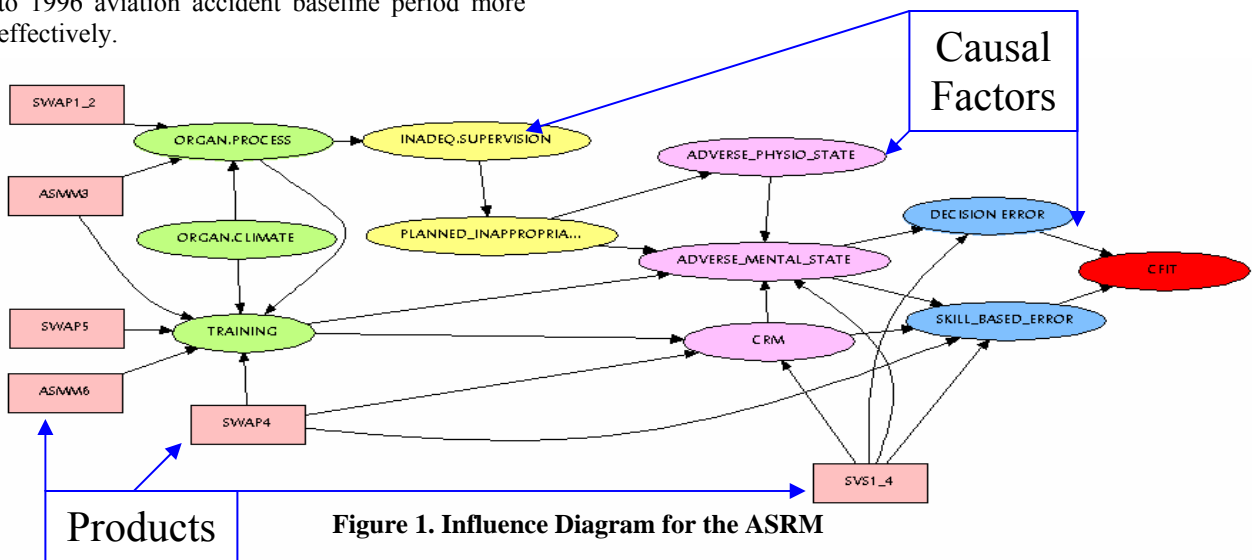
INTRODUCTION

To facilitate knowledge transfer in the fast-paced world of aviation, the field requires an exhaustive method to extract and display information from models built specifically for aviation. The *Aviation System Risk Model (ASRM)* evaluates impacts of new technologies and safety products utilizing Bayesian probability theory and Bayesian decision theory. The *Human Factors Analysis and Classification System (HFACS)* and NASA's individual aviation products are used in a general analytic framework to determine the relative and absolute improvement of individual and multiple technology combinations.

ABSTRACT

An Executive Information System (EIS) provides a methodology to expose high-level knowledge gleaned from models and databases. The EIS in this paper gathers its information from the Aviation System Risk Model or ASRM¹ that is a collection of Bayesian Belief Network (BBN) models utilizing the Human Factors Analysis and Classification System (HFACS). Aggregation of the knowledge is then processed into three different knowledge displays - an accident case display, Haddon Matrix and Multi-Factor Plots. Through the knowledge displays developed for the EIS a manager or an executive may be able to analyze and investigate the 1990 to 1996 aviation accident baseline period more effectively.

A Bayesian Belief Network (BBN) with HFACS supplemented by some other non-human causes (ovals) and products (rectangles) is displayed in Figure 1. When the products are introduced into the BBN, the model is referred to as an Influence Diagram. The products can only be in a state of on or off.



Each causal factor is connected by links that capture the probabilistic interdependencies among the causal factors (or nodes). The ASRM methodology builds upon accident models to discover useful information about NASA's product portfolio.^{1,2,3,4,5,6}

The Bayesian Belief Network contains nodes (i.e., causal factors) that are linked to one another in a probabilistic fashion. These linkages encapsulate the dependencies among the nodes. Each model in the ASRM is built by using accident synopses, books about the accident, and/or NTSB reports. After review by subject matter experts, the model is fully quantified during the conditional probability elicitation process. Each node is designated according to either the HFACS taxonomy conceived by Shappell and Wiegmann¹¹ or alternatively a non-human cause, such as weather (i.e., snow).

AvSP TECHNOLOGY SUITE

In 1997, the NASA in partnership with the FAA launched the Aviation Safety Program (AvSP) to develop products that would reduce the aviation accident rate by a factor of 5 by 2007.³ These 48 technology products are targeted to mollify mechanical, software, or human factor related issues surrounding aviation accidents to thus improve the safety of flight. Of the seven suites only Accident Mitigation (AM) is usually applied after the accident has occurred. All seven product suites are elaborated below:

- Aircraft Icing (AI) alerts pilots to discuss procedures and concepts about icing on aircraft. Experimental methods, computational tools, and atmospheric characterization technologies will be developed to ameliorate issues associated with Aircraft Icing (AI).

- Aviation System Modeling and Monitoring (ASMM) provides decision-makers with an insightful method to monitor the performance and safety of the National Airspace System (NAS). This product suite is aimed at analyzing data in to use in the assessment and simulation of system-wide risk for officials and Air Traffic Control (ATC).

- System Wide Accident Prevention (SWAP) addresses and ameliorates many of the concerns of human error and non-compliance. In excess of 60% to 80% of accidents may be connected to human errors. There are products to assist pilots with cockpit automation and maintenance risk tools under development.

- Single Aircraft Accident Prevention (SAAP) alerts pilots to loss of control and vehicle system failures. Automated recovery from unusual aircraft attitudes and vehicle health management sensors are encapsulated in this product suite.

- Weather Accident Prevention (WxAP) aims to reduce the negative impact of the atmosphere. Radar data is collected and compared to the true winds. A turbulence radar system for cockpit integration is also among the products in this suite.

- Accident Mitigation's (AM) main purpose is to reduce the death rate in survivable accidents. For example, energy absorbing seats and dynamic crash analysis software are currently being developed.

- Synthetic Vision Systems (SVS) creates terrain, obstacle, and airport databases for enhanced GPS/DGPS navigation. This suite addresses situational awareness and the safety hazard of limited visibility. (<http://avsp.larc.nasa.gov/about.html>)

RESEARCH PROBLEM

The risk models developed for the AvSP product insertion into the ASRM facilitate a top-level evaluation of the interactions that occur across all models. Displays must be created to have a better understanding of the interactions of the products. Aggregate data from accident models and categories must be rendered to gain a good understanding of the work accomplished to date. Figure 2 displays the multi-case design of the ASRM that currently comprises 20 accident models.

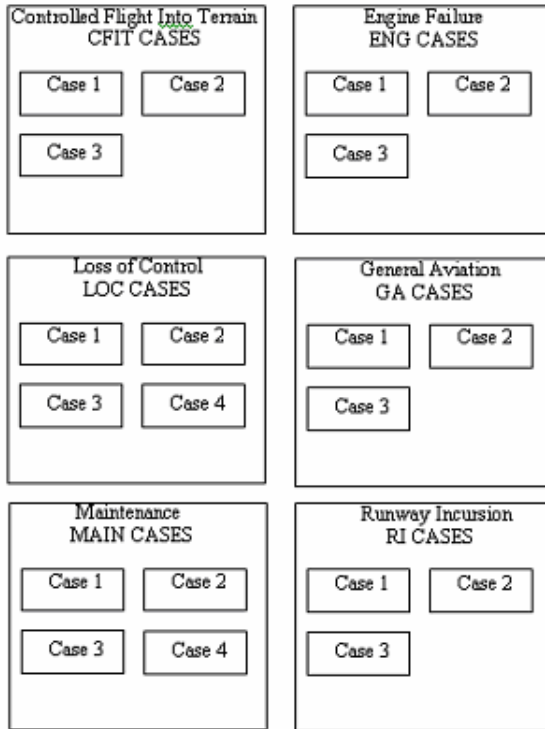


Figure 2. ASRM Cases and Categories

Through this paper, knowledge displays are constructed from these 20 models. The validation of the models requires the side-by-side comparison of the various combinations of products and causal factors with a check-list. Also, there must be a method to provide feedback into the process and models, so that robustness of the results may be progressively increased.^{13, 14}

RESEARCH METHODOLOGY

Executive Information Systems (EISs) originate in Decision Support Systems in the mid-1980's. An EIS's main attribute is to provide the support and crucial knowledge to assist organizational objectives. Data mining from data warehouses and internal data provide information about the relationships that are hidden in the data. Although most EISs gather data from data warehouses, the models developed from the NASA contract (NAS1-03057) under Luxhøj are gleaned to give relevant information for upper level management at NASA. External information for the EIS is provided by the Volpe Center, the FAA, NASA and the NTSB.

An EIS typically supports environmental information, strategy formulation and strategy implementation. Although an EIS's intent is not to directly support an organization's objectives, an EIS may guide the organization to a better solution, whether that is cost, time, or reducing the accident rate. Indirectly the EIS supports the overall objectives of an organization, since planning becomes more of an approachable topic. Table 1 outlines the support that an EIS generally furnishes after development

The four areas that an EIS bolsters in an organization are Organizational Objectives, Environmental Scanning, Strategy Implementation, and Strategic Control. These areas of investigation are necessary for any organization to reach a higher level of desired and achievable results.

Table 1. Types of EIS Support⁹
(Source: Watson and Frolick, 1993)

Phase	EIS Support
Organizational Objectives	No Direct Support.
Environmental Scanning	Provide access to electronic databases. Provide access to specially prepared environmental information. Applications for sharing soft information.
Strategy Implementation	Provide information about project plans. Facilitate communication and coordination of work activities. Support budgetary process.
Strategic Control	Compare actual performance against budgets, goals, standards, benchmarks. Support drilldown to underlying detail data. Monitor the accomplishment of objectives.

Three methods are used to display the information catalogued in databases for the ASRM. These methods are accident case displays, Haddon Matrices and Multi-Factor Plots. Examples of each type are explored for their potential benefits. Management displays or accident case displays for each of the cases are

developed to portray the models “best” scenarios overall and with different product suites turned on and off. This information should be condensed, so the uniqueness of different scenarios may be easily acquired by an analyst. An example of the preliminary EIS display is depicted in Figure 3.

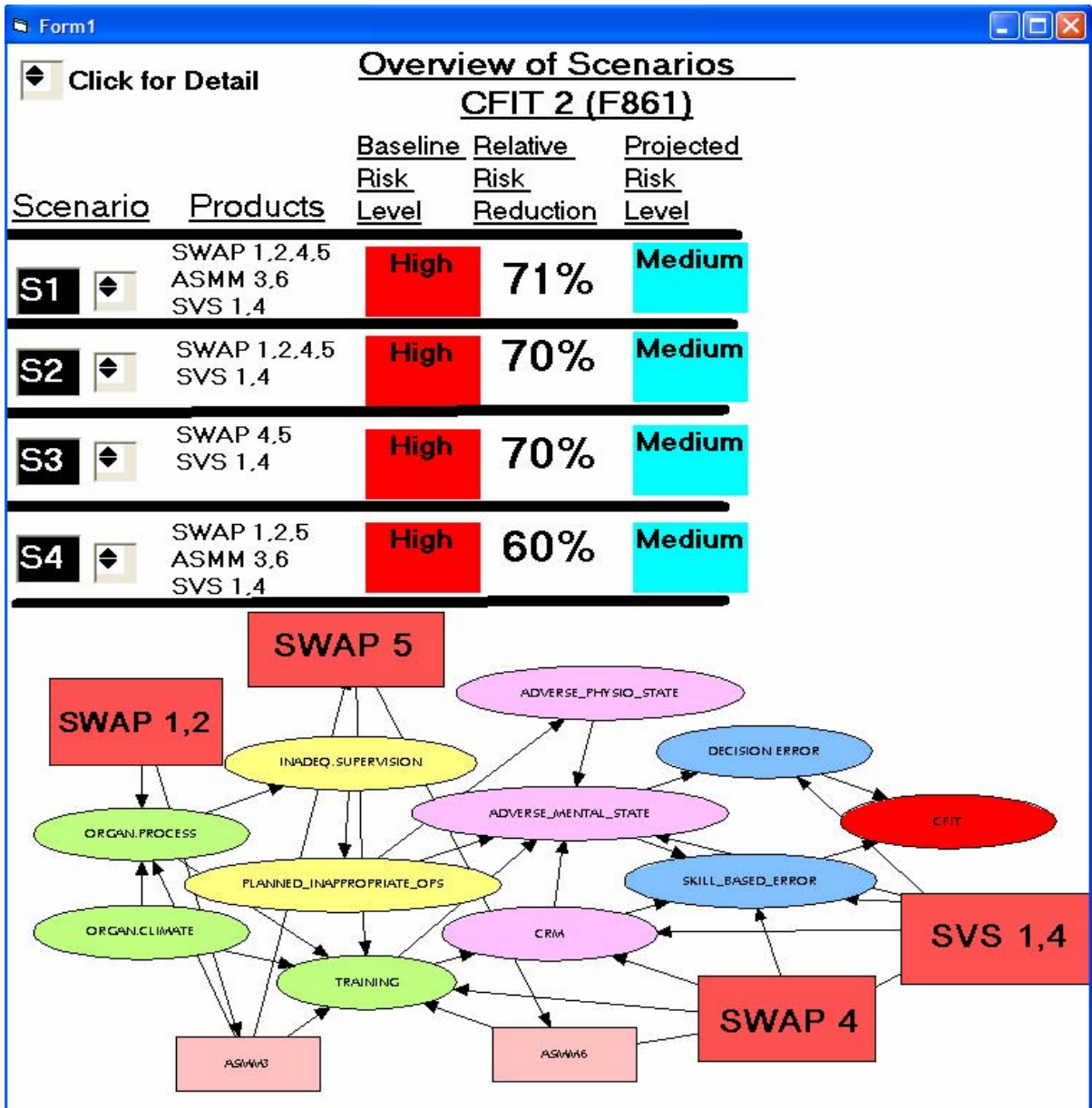


Figure 3. CFIT 2 Case - Accident Case Display

A traditional method to classify safety management practices is to place the information into a Haddon matrix that differentiates the role of the human, vehicle and environment. This matrix proposed by Haddon in 1970 is also divided into pre-crash, crash, and post-crash

phases. Since the BBNs capture and exploit the interactions of the phases and features of the accident, the traditional downfalls of Haddon compartmentalization are overcome.^{15,16} An example is displayed in Figure 4.

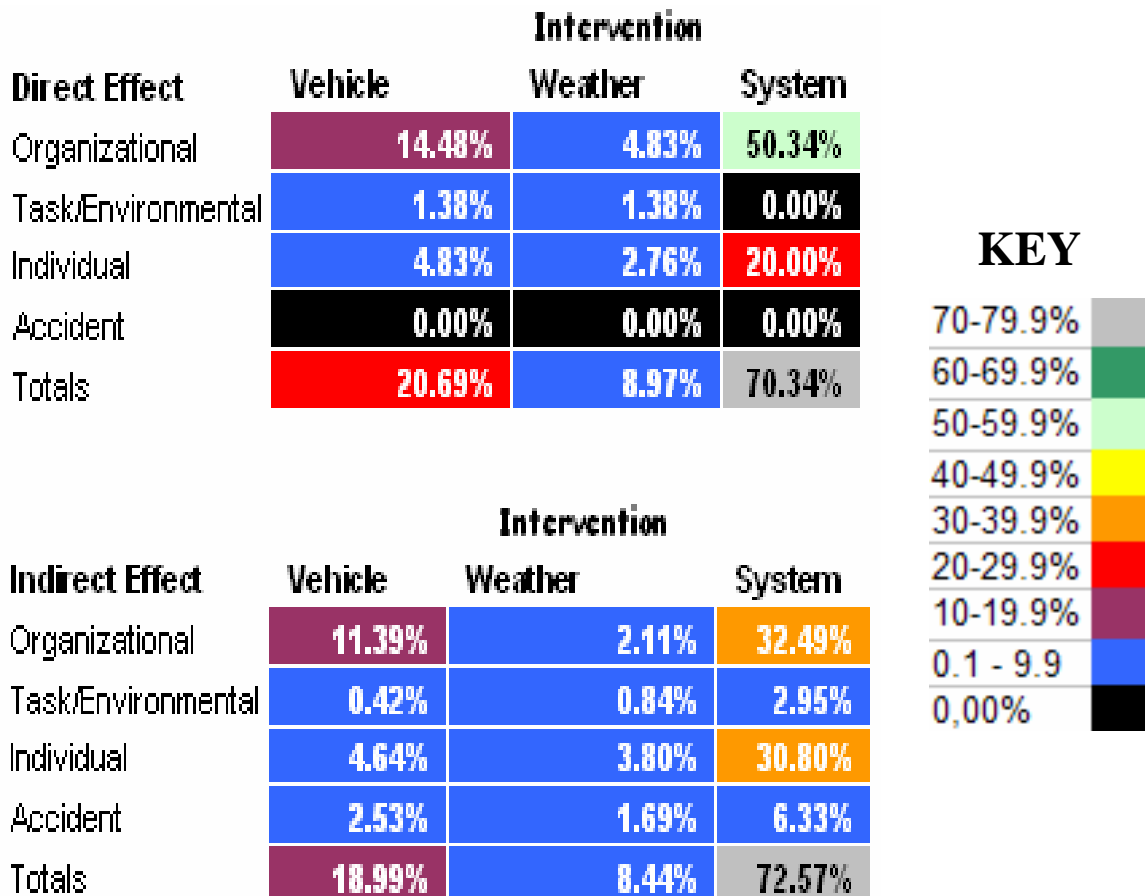


Figure 4. Haddon Matrix Example

Many pieces of useful information may be drawn from the two Haddon matrices depicted above. These two matrices are the total connections of products to different causal factor groupings for both the direct and indirect effects. Direct effects are present when there is an immediate link from a product to a specific node. On the other hand, indirect effects occur when there is another node in between a product and a causal factor.

Myriad analyses may be accomplished when the Haddon matrix is produced. Across the 20 models, 70.34% of the total direct effects are System products. Also, 72.57% of the indirect effects are System products. Percentage-wise the number of times a System product may be used indirectly compared to the total number of times a product is utilized goes up slightly.

More in depth analysis of this graph provides the following detail. The percentage of times a System product is used on the Organizational causal factors directly is 50.34%. In comparison, only 32.49% are accounted for in total due to indirect linkages. Contrary to the previous example, 20% of the time the System products directly affects the Individual; whereas, there is a large increase to 30.80% of the time a System product affects the Individual. This increase is due to the number of interactions a System product may have through the Organization to the Individual.

Figure 5 depicts the relationships existing in Leavitt's study. Captured in Leavitt's model are the complex relationships between people, tasks, technology and organizational structures. Leavitt in 1965 developed a model of organizational interactions depicted in Figure 5.
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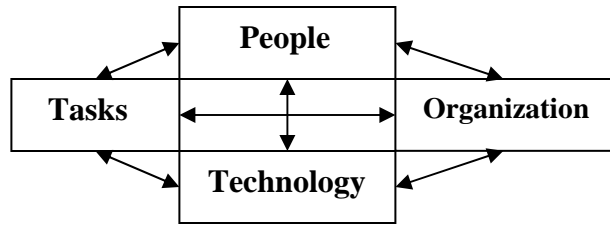


Figure 5. Leavitt's Model of Organizational Interactions

The average maximum percentage decrease of a single AvSP product and the average minimum percentage decrease of a single product upon Organization, Human, Environment, and Accident groupings are depicted in Figure 6-7, respectively. These Multi-factor Plots parallel Leavitt's model of Organizational Interactions. Human, Organizational, Environmental, and Accident are substituted for People, Organization, Tasks, and Technology, respectively.

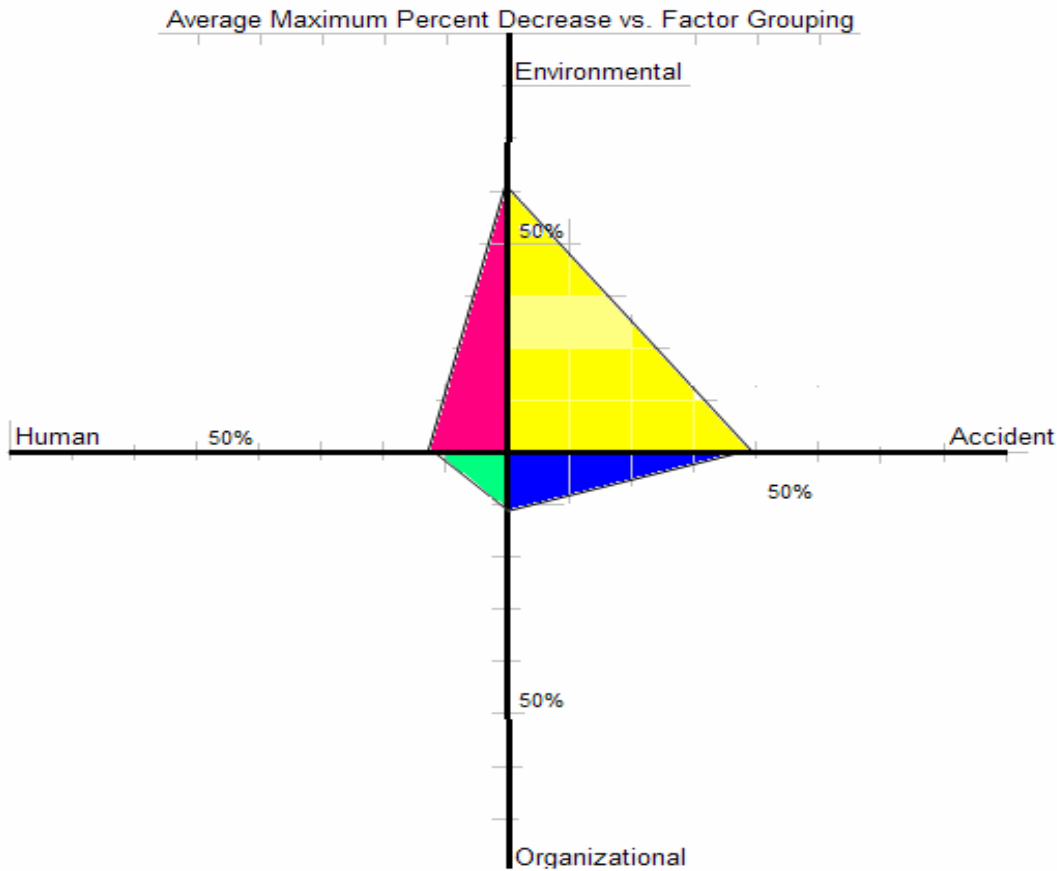


Figure 6. Average Maximum Percent Decrease vs. Factor Grouping

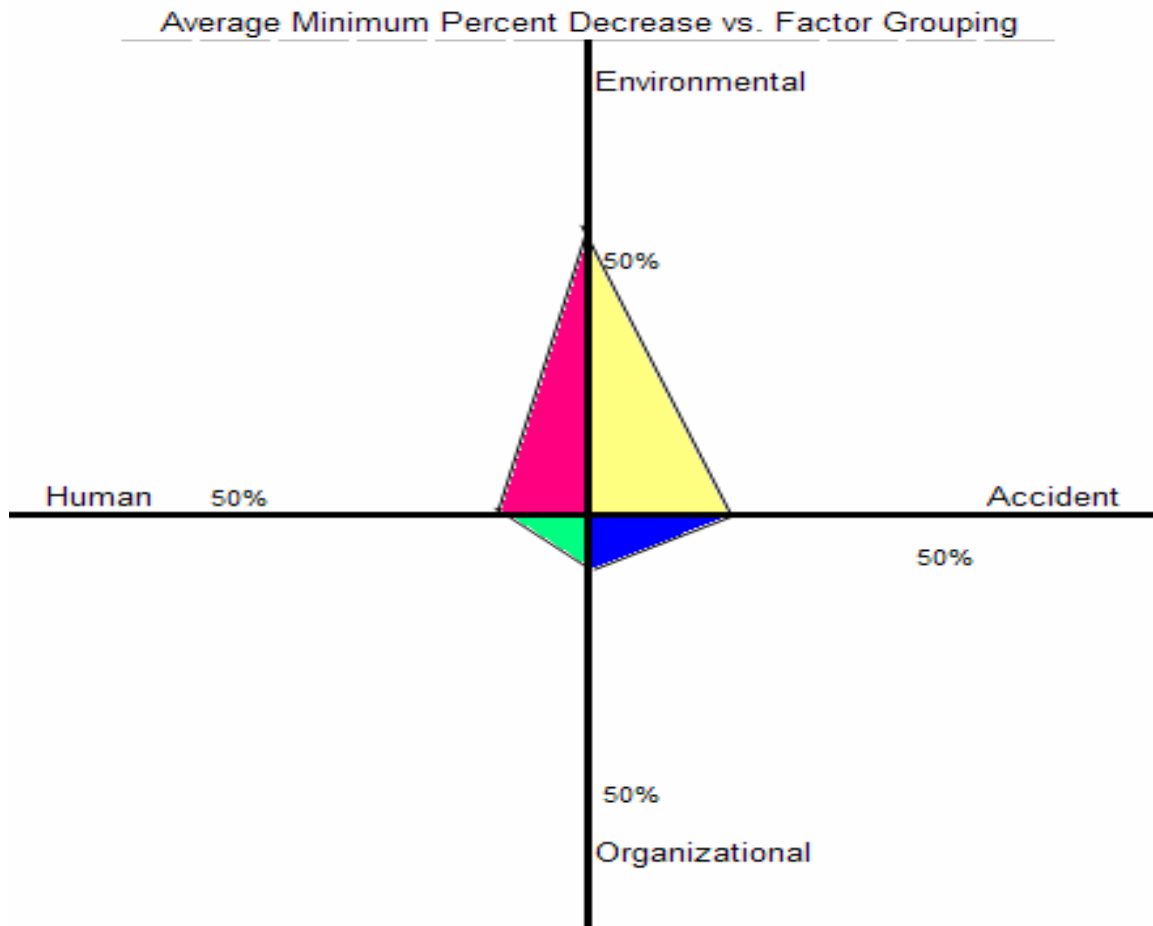


Figure 7. Average Minimum Percent Decrease vs. Factor Grouping

There are numerous ways to analyze these graphs both separately and among numerous diagrams.

Each graph displays is the average maximum or minimum percent decrease vs. each factor grouping. Examples of this are the 10.86%, 52.61%, 12.32%, and 39.30% average maximum percent decrease for Organizational, Environmental, Human, and Accident group factors, respectively. Further analysis of this diagram shows that there are colors in each quadrant that represent the space between two groupings (i.e., Environmental-Accident, Human-Organizational). As these shaded regions grow larger there is more of a reduction

of the average percent decrease for each combination of groupings. A larger shaded region represents a lower likelihood of that combination of groupings appearing.

Figure 7 displays the average minimum percent decrease vs. factor grouping. Examples of this are the 9.35%, 48.36%, 10.25%, and 18.56% average minimum percent decrease for Organizational, Environmental, Human, and Accident group factors, respectively. The accident grouping has the largest difference between the average maximum and average minimum percent decrease per product evaluated; whereas, the Organizational group has the smallest per product evaluated.

EVALUATION

There are numerous queries that may be executed through the twenty models developed for the NASA AvSP. As an example, the accident likelihood may be evaluated independently. Each accident is evaluated independently and the results are presented to show the relative decrease from the 1990-1996 baseline. After running multiple scenarios, the best results are shown in similar diagrams as in Figure 3.

Benefits from the accident case display are that the user of the ASRM may now see different scenarios pictorially. The ASRM provides decision-makers a method to compare and contrast different combinations of products on the accident risk. Although there is a quick way to compare the accident risk, accident case displays do not provide multiple levels of information about interactions or about summary statistics cross-case. Haddon Matrices and Multi-Factor Plots supply this knowledge.^{13,14}

Figure 4 gathers information about how many times a certain product is utilized across all 20 models. This Haddon matrix provides detailed information in order to complete a gap analysis and to determine the level of future research. This type of information output is useful, since it is condensed and may be used in future calculations.

On the other hand, Multi-Factor Plots are more similar to the accident case displays. They determine the average maximum and average minimum percentage decreases that a product may have on a group of nodes. There is a significant amount of information that may be acquired from a set of Multi-Factor Plots, since they are 4-axes graphs.

CONCLUSIONS

Each type of knowledge display explores different types of knowledge acquirement and dissemination. There is no “correct” way to display information, only a myriad of ways which in culmination may emphasize the nuances of the data that is catalogued and placed into a database. Therefore, each knowledge display holds unique properties and may be analyzed in many different respects. Table 2 offers a summary of the pros and cons of accident case displays, Haddon Matrices, and Multi-Factor Plots. Research is underway to modify and refine the EIS displays based on inputs from the NASA AvSP managers and executives.

Table 2. Pros and Cons of Knowledge Profiles

Knowledge Display	Pros
Accident Case Display	Easy to use and utilize. Compare many interactions. May be used for any one metric. Graphical.
Haddon Matrices	Displays a multitude of information. Easy to cross-reference different Metrics. Fairly easy to use. Calculations may be performed.
Multi-Factor Plots	Provides complex information in a small amount of space. Compares different matrices. Graphical.
Knowledge Display	Cons
Accident Case Display	Simplistic. Compares only one metric. Not easy to utilize again.
Haddon Matrices	Numerous levels of information to analyze. Moderate level of difficulty to understand.
Multi-Factor Plots	High level of complexity. Requires more knowledge to utilize effectively.

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APPENDIX

BBN – Bayesian Belief Network
EIS – Executive Information System
ASRM – Aviation System Risk Model
NTSB – National Transportation Safety Board
HFACS – Human Factors Analysis and Classification System
AvSP- Aviation Safety Program
NASA – National Aeronautics and Space Administration
AI – Aircraft Icing
ASMM – Aviation System Modeling and Monitoring
NAS – National Airspace System
ATC – Air Traffic Control
SWAP – System Wide Accident Prevention
SAAP – Single Aircraft Accident Prevention
WxAP – Weather Accident Prevention
AM – Accident Mitigation
SVS – Synthetic Vision Systems
CFIT – Controlled Flight Into Terrain
LOC – Loss of Control
MAIN – Maintenance
FAA – Federal Aviation Administration
Air Carrier WS – Air Carrier Work Scope
AMS – Adverse Mental State
APS – Adverse Physiological State
CRM – Crew Resource Management
DE – Decision Error
Deicing_Ops – Deicing Operations
Design_Tech_Environ – Design Technical Environment
Environ_Cond – Environmental Conditions
GPS – Global Positioning System
DGPS - Digital Global Positioning System
AOPA - Aircraft Owners and Pilot Association