A Delphi Study of Decision Support Systems for Aviation Safety Management Program Cost Estimation

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Abstract

Safety management is a major issue in the aviation industry and professionals in the field of aviation safety management have only recently begun to use advanced business management practices to address viable ways to determine the cost of safety initiatives in this complex environment. Research on different modeling efforts related to safety performance evaluation indicated the financial implications of aviation safety programs have not been addressed to determine the actual benefits or losses on such an investment. The problem addressed in this study was safety management system (SMS) programs have not always been implemented in the aviation industry, as actual program costs could not be determined comprehensively and definitively. In this study, participants identified key factors that were used to develop a decision support system framework for SMS program cost estimation. A descriptive qualitative method was used and included a purposeful sample of a Delphi panel of four aviation management experts in project management and cost analysis for project planning who were queried across three rounds of structured inquiry procedures. The data derived from the study addressed the need for a management decision-making model for SMS cost estimation that is conceptually grounded in quality management principles. Data analysis included Delphi stability analysis, as well as familiarization, identification, indexing, charting, and mapping. From these analyses, a decision support framework for SMS program cost estimation was revealed. The study used activity based costing principles to develop SMS cost estimation tools that could be used by decision makers prior to SMS program implementation. Three recommendations were offered for professional practice: (a) rulemaking (regulatory) improvements that will support the quality of data available for

research, (b) improvements to guidance material that will support SMS program strategies, and (c) information technology (IT) improvements that will support future analysis of benefits of SMS programs. Four recommendations for future research were offered: (a) links of safety initiatives to business advantage, (b) barriers to the collection of financial data, (c) case studies for empirical evidence of program costs, and (d) theoretical development.

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Chapter 1: Introduction

Beliefs about safety in the aviation industry have moved toward a business perspective in organizations (Flouris & Kucukyilmaz, 2009). Although implementation of safety management system (SMS) programs has been a top priority in the aviation industry, the cost of the safety initiatives has limited SMS program implementation (Avers, Johnson, Banks, & Nei, 2011; Lu, Schreckengast, & Jia, 2011; Yantiss, 2011). The lack of decision support systems for SMS program cost estimation may indicate the slow progress of the implementation of voluntary safety programs in the aviation industry (Chilester, 2007; Lowe, Pfeiderer, & Chidester, 2012). Some managers may have proceeded with SMS program implementation without a complete understanding of the cost effect to their organization (Liou, Yen, & Tzeng, 2008). This may have been counterproductive to the business approach as suggested by SMS reference documents (International Civil Aviation Organization [ICAO], 2009; Transport Canada, 2008; UK Civil Aviation Authority [UKCAA], 2010; U.S. Department of Transportation [DOT], 2010). Only 35% of the total cost of a system has been typically incurred during acquisition, and the remaining costs expended in the sustainment, operation, and support of the total life cycle of the system (Barringer & Weber, 1996).

Several researchers in other domains have emphasized the importance of business objectives, but failed to provide cost-benefit analysis for engagement decisions (Markos & Sridevi, 2010). Preacquistion activities can significantly reduce the risk of cost and improve program performance (Meier, 2008). The Federal Aviation Administration (FAA) program guidance indicated that costs should be collected (DOT, 2010); yet, no known empirical studies have identified SMS cost estimation models to identify management strategies and key performance indicators apart from perceived cost benefit in the context of risk mitigation (Lercel, Steckel, Mondello, Carr, & Patankar, 2011; Rosenkrans, 2012).

In project management, constructs are typically categorized into three success factors of (a) time, (b) cost, and (c) quality (Bryde, 2008), and the difficulty in quantifying the cost of safety initiatives may be attributed to the lack of financial data collection for trend analysis or risk assessment (Briciu & Capusneanu, 2010; Cox & Flouris, 2011). Trend analysis related to project management studies has also shown that many projects fail due to inadequate planning and cost trending (Conboy, 2010). Phillips, Brantley, and Phillips (2012) noted that poorly managed projects in the United States cost companies an estimated $250 billion annually. According to the Business Improvement Architects (2006), just 2.5% of global businesses achieved 100% project success, and 87% of businesses did not align project strategies to control costs.

Chapter 1 contains the introduction to the study and includes background information, the problem statement, purpose of the study, theoretical framework, research questions, nature of the study, significance of the study, definitions, and summary of the chapter. The background section includes a discussion of the research topic. The problem statement and purpose of the study document the intent of the study. The theoretical framework identifies the broad area of research followed by the research questions the study will answer. The nature of the study provides a brief explanation of the study design. The significance of the study explains the importance of the study followed by a brief list of definitions. The summary provides a review of Chapter 1.

Background

Since the 1990s, the aviation industry has achieved notable safety improvements resulting in low accident rates (Ananda, Kumar, & Ghoshhajra, 2010; Flouris & Kucukyilmaz, 2009; Johnson, Kirwan, Licu, & Stastny, 2009; Layton, 2012; Mitchell & Leonhardt, 2010; Oster, Strong, & Zorn, in press). In 2010, the Airline Safety and Federal Administration Extension Act was formally enacted, and as part of its policy directive, directed the FAA to implement a final rule requiring all part 121 air carriers to establish a formal safety management system. However, recurring issues such as concern about data misuse and the capability of cost justification have been identified as problematic to participation in voluntary safety programs (Avers et al., 2011; Logan, 2008, Lowe et al., 2012). Further, some aviation organizations that have implemented SMS programs have not experienced measurable benefits (Kindle, 2011; Thomas, 2012). In contrast, Line Operation Safety Audits (LOSA) have been reported to have shown safety benefits and financial savings (Avers et al., 2011). However, there have been no known empirical studies linking safety benefits or financial savings to LOSA in the aviation industry.

While the number of aviation accidents has been declining, the cost of mishaps continues to be a problem (*Aviation safety*, 2012; U.S. Government Accountability Office [GAO], 2007, 2012). The Flight Safety Foundation, an aviation research organization, reported that in 2004, ground mishaps worldwide cost air carriers $10 billion annually (GAO, 2007). The National Business Aviation Association (NBAA) safety committee estimated ground mishaps cost the general aviation industry more than US$100 million annually (Business Aviation Insider, 2012). In Australia, the total cost of civil aviation accidents was an estimated AUS$114 million for 2003-2004 (Australian Government Bureau of Transport and Regional Economics, 2006).

The FAA (2010d) estimated that the total benefits for SMS programs are $1,143.1 million. Informal analysis by the Aviation Suppliers Association (ASA) (2011) indicated a typical SMS program implementation for a company would result in $1.1 million in annual staff costs alone. Both the ASA and the Modification and Replacement Parts Association (MARPA) (2011) purported that the FAA cost-benefit analysis was poorly represented in the notice of proposed rulemaking (NPRM). In addition, further research is needed to investigate unsolved concerns from the aviation industry where similar regulations have been proposed for FAR Part 139 airport operations (Lu, Schreckengast, et al., 2011).

According to Galotti, Rao, and Maurino (2008), efficient and effective management of any organization requires the management of basic business processes such as financing, budgeting, communicating, and allocating resources. Regulatory oversight in the aviation industry is shifting from reactive to proactive or data-driven, risk-based approach (*Aviation Safety*, 2012; Flouris & Kucukyilmaz, 2009; GAO, 2012). The industry is shifting to data-driven, risk-based safety oversight approach (GAO, 2012). Some practitioners have posited the economic burden for safety oversight has shifted from regulatory authorities to self-regulation by the aviation industry (Atak & Kingma, 2011; Grote, 2012; Hopkins, 2011; Lacagnina, 2009; Stoop & Dekker, 2012). The voluntary reporting systems are "absolutely critical to safety management" since they provide data necessary to provide educated predictive and proactive safety action (Avers et al., 2011, p. 13).

The FAA (2010b) program guidance for Part 139 (airport) SMS implementation indicated costs should be collected. There have been, however, no known empirical studies that have identified SMS cost estimation models to identify management strategies and key performance indicators apart from perceived cost benefits in the context of risk mitigation (Lercel et al., 2011; Rosenkrans, 2012). Cost estimation alone is a challenging task and is crucial to financial success in competitive environments (Qian & Ben-Arieh, 2008). The airline industry is one of the largest service fields in the U.S. economy but has experienced severe financial distress since 2005 (Ribbink, Hofer, & Dresner, 2009). According to the International Air Transport Association (IATA, 2009), financial losses to airlines were estimated to be US$5.6 billion in 2010. Implementation costs and unknown return on investment (ROI) have been major deterrents to the implementation of SMS within an industry already plagued with financial burdens (Hofer, Dresner, & Windle, 2009; Lacagnina, 2009; Lin & Chang, 2008; Roman, 2011; Wilson, 2010). The lack of decision support systems for SMS program cost estimation may indicate the slow progress of the implementation of voluntary safety programs in the aviation industry (Chilester, 2007; Lowe et al., 2012).

The difficulty in quantifying the cost of safety initiatives may be attributed to aviation authorities and organizations not collecting financial data with the intention to conduct cost-benefit analysis or trend analysis (Briciu & Capusneanu, 2010; Wang, Hofer, & Dresner, 2013). Government authorities have acknowledged problems exist addressing the occurrence of incidents in ramp areas, which "were hindered by the lack of data on the nature, extent, and cost of such incidents and accidents" (GAO, 2012, p. ii). Trend analysis related to project management studies has also shown that many projects fail due to inadequate planning and cost trending (Conboy, 2010). For example, Phillips et al. (2012) noted that over $250 billion was spent annually on poorly managed IT projects in the United States (U.S.) with 52.7 percent of the projects exceeding 189 percent of the allotted budget. According to the Business Improvement Architects (2006), just 2.5% of global businesses achieved 100% project success, and 87% of businesses did not align project strategies to control costs.

Balancing business risks associated with not just accidental losses, but financial risk from value creating activities, is an ever-present challenge to airlines maintaining a competitive business (Yilmaz, 2008). Organization leaders responsible for managing strategic business goals to remain competitive while balancing safe levels of operation are often faced with potentially conflicting goals (Hendershot, 2010; Lofquist, 2010, 2011; Pettersen & Aase, 2008: Rasmussen & Lundell, 2012; Woods, 2009). Managers are also often faced with making risk decisions to manage conflicting goals such as budget constraints, operations and production schedules, and safety (Woods, 2009). Westbrook (1995) suggested that operations management academics must develop new theories from observation of actual practice. Anderson, Rungtusanatham, and Schroeder (1994) proposed a theory of quality management based upon W. Edward Deming's writings, specifically, the Deming Management Method. The theory of quality management has the potential to contribute to operations management and safety theories.

Problem Statement

The problem is SMS programs have not always been implemented in the aviation industry, as actual program costs could not be determined comprehensively and definitively (Avers et al., 2011; Rosenkrans, 2012; Lu, Young, Schreckengast, & Chen, 2011). Consequently, the implementation of voluntary aviation safety programs has remained stalled (Chilester, 2007; FAA, 2010c; Lowe et al., 2012). Although the ICAO SMS program model (ICAO, 2009) identified key factors such as task time standards, it did not include other key factors typically needed for program management and transparency of safety and financial risks (Lu, Young, et al., 2011; Mitchell & Braithwaite, 2008). Further research was needed to identify key factors of SMS models in order to link costs to business advantage (Cox & Flouris, 2011; Rosenkrans, 2012). No tested decision support framework to address SMS program cost estimation in the aviation industry has existed (Lu, Young, et al., 2011; Madsen, 2013; Wong & Yeh, 2007). Implementation costs and unknown ROI have been also been major deterrents to the implementation of SMS within an industry already plagued with financial burdens (Lacagnina, 2009; Lin & Chang, 2008; Wilson, 2010). Current worldwide aviation accident rates have been the lowest in history (Australian Transportation Safety Bureau, 2011; European Aviation Safety Agency, 2010; FAA 2010c; International Air Transportation Association [IATA], 2012); yet, 16% of all 2011 accidents were attributed to ground damage, up 11% from 2010 (IATA, 2012). In 2009, ground damage cost the aviation industry US$4 billion annually (IATA, 2010). One of the goals of SMS is to ensure the risks of conducting normal business are identified and risks are mitigated to maintain organizational control (ICAO, 2009, 2012). Regulatory authorities have acknowledged associated problems within the aviation industry such as (a) data analysis and staffing problems, (b) limited access to voluntary reported data, (c) participant concerns with FAA access to voluntary data, and (d) lack of data to assess the safety performance of certain industry sectors (FAA, 2010c).

Purpose

The purpose of the qualitative study was to identify key factors in the use of a decision support system framework for SMS program cost estimation. Specifically, it explored how SMS cost estimates may be modeled using existing information sources to provide decision makers with a framework for SMS program strategies (Lu, Young, et al., 2011). The degree of relevance and the need for inclusion of the key factors for a decision support system framework were determined by a selected group of aviation management experts. The reason was that such experts possess a broad understanding of project management and project cost analysis. The identification of key factors were used in tandem to other elements to develop a decision support system framework by which SMS program cost estimation in the aviation industry can be conducted (Hasson & Keeney, 2011; Keeney, 2010; Linstone & Turoff, 2011). The theory of quality management provided the theoretical foundation to approach the research problem (Anderson et al., 1994). The qualitative study design employed a modified Delphi technique to allow for a panel of aviation industry experts to contribute a critical knowledge base in the area of SMS program cost estimation to the study (Linstone & Turoff, 2011). The Delphi panel consisted of four aviation management experts in project management and cost analysis for project planning. The study was conducted in Houston, TX, and data was obtained using an online questionnaire to permit expert participation from multiple geographic locations, through three Delphi rounds to synthesize a framework to identify key parameters and methods for managing the total cost of SMS program development using activity-based costing (ABC) principles

(Keeney, 2010; Linstone & Turoff, 1975).

Theoretical Framework

The theoretical basis of the study incorporated the ABC principles (Cooper & Kaplan, 1999) and the theory of quality management (Anderson et al. 1994). A discussion of the principles and theory serves to explain the building blocks of the theoretical framework applicable for a decision support system for SMS cost estimation.

Theory of quality management. The theory of quality management was proposed by Anderson et al. (1994) and was traced to the teachings of W. Edwards Deming (1900-1993). Deming was influenced by his mentor Walter A. Shewhart (1891-1967) and the work of Charles Irving Lewis' (1883-1964) theory of knowledge (Anderson, 1994; Mauleon & Bergman, 2009). The theory of quality management

> concerns the creation of an organizational system that fosters cooperation and learning for facilitating the implementation of process management practices, products, and services, and to employee fulfillment, both of which are critical to customer satisfaction, and ultimately, to firm survival (Anderson et al., 1994, p. 473).

According to Anderson et al., there are seven concepts underlying Deming's management method: (a) visionary leadership, (b) internal and external cooperation, (c) learning, (d) process management, (e) continuous improvement, (f) employee fulfillment, and (g) customer satisfaction. The role of leadership is emphasized with the theory of quality management in order to move an organization toward continuous improvement and to create an organizational system receptive to process management practices (Anderson et al., 1994).

Deming's contribution to quality management was noted throughout the literature (Clegg, Rees, & Titchen, 2010; Delmonte, 2011; Keeble-Ramsay, & Armitage, 2010; Knouse, Carson, P. P., Carson, K. D., & Heady, 2009; Liang & Zhang, 2010; Mauléon & Bergman, 2009; Redmond, Curtis, Noone, & Keenan, 2008; Reid, Brown, Case, Tabibzadeh, & Elbert, 2011). Quality management systems (QMS) typically focus on continuous improvement within organizations (Stolzer, Halford, & Goglia, 2011), and was one contribution to the quality and safety disciplines made by Deming (Knouse et al., 2009; Mauléon & Bergman, 2009). In the safety discipline, developing formal policies and work practices improve workplace safety by adapting best practices to eliminate or control potentially hazardous practices followed by audits and management review (Levine & Toffel, 2010). Linstone and Turoff (2001) postulated organizations "should have a principal goal to understand even the smallest mistakes and to improve the situation" (p. 1717). The theory of quality management underlying Deming's (1986) management method suggested links to data that could be used to identify accident precursors.

ABC principles. The theoretical basis for a proposed decision support system for SMS program cost estimation included ABC principles. Although some researchers (Liu & Pan, 2007) consider ABC to be at a theoretical level, ABC principles have been applied to enhance the theoretical development in manufacturing systems designs (Basti, Grubic, Templar, Harrison, & Fan, 2010; Singer & Donoso, 2008) and improve business management decisions (Baykasoglu & Kaplanoglu, 2008; Novak, Paulos, & St. Clair, 2011). In contrast, some researchers explained that ABC principles are not useful in design stages because life cycle costs are not typically known to designers (Liu, Quynh,

& Ng, 2009). Advances in the field of accounting have led to the development of ABC principles and modifications of these principles (Ayvaz & Pehlivanli, 2011). Activity-based costing differs from traditional cost accounting by means of choosing smaller cost pools that capture all the inputs into a particular process (Basti et al., 2010; Briciu & Capusneanu, 2010). Briciu and Capusneanu (2010) explained that ABC principles incorporated production costs, fixed costs, variable costs, total cost, direct costs, and indirect costs (overhead). Some researchers and practitioners believed that while ABC principles are feasible for pilot studies, it was difficult and costly to scale to company-wide applications due to the existing organizational culture (Basti et al., 2010). Interest in ABC principles have been aroused by the number of companies using balanced scorecards for decision-making; however, there was typically a lack of data to support various planning factors (Ayvaz & Pehlivanli, 2011).

In relation to the ABC model, the scope of project activities is typically identified in a contract statement of work (scope), engineering drawings, quality manual, or industry standard, and the activities are managed by the project team using various tools, such as a work breakdown structure (WBS), bar graphs and charts (Jung & Kang, 2007; Kwak & Anbari, 2011; Stolzer et al., 2011; Trivailo, Sippel, & Sekercioğlu; 2012). A work breakdown structure is used in project management to reduce the overall objective into greater detail or work packages so that individual tasks can be accomplished and cost estimation can be accomplished (Stolzer et al., 2011; Trivailo et al., 2012). According to Phillips et al. (2012), a detailed WBS is necessary in the planning stage of projects to reduce extra work and resources used for the project, which equates to reduced costs and time. The scope of the project must clearly identify requirements in terms defined by the stakeholders such as quality, time, and cost (Marouni, 2010) and can be divided into small components to improve cost accuracy, schedule, and resource estimates. Safety professionals have suggested the inclusion of ABC principles to collect financial data, as a means to make a business case for safety initiatives (Jallon, Imbeau, & de Marcellis-Warin, 2011; Liu, Hwang, & Liu, 2009; Rosenkrans, 2012; Tsai & Hsu, 2008).

Research Questions

This qualitative study included the development of a decision support system framework for SMS program cost estimation. The study sought to determine key SMS program cost parameters to provide decision makers with a framework for SMS program strategies. The research questions that guided the study were as follows:

Q1. What do experts in the aviation industry perceive are the key factors in the development of a decision support system for SMS cost estimation?

Q2. How can SMS project cost estimates be modeled using existing information sources in the aviation business environment?

Nature of the Study

A descriptive qualitative method was selected to develop a decision support system framework for SMS program cost estimation. The study established the validity of the initial drivers provided in the ICAO SMS project model. A Delphi technique was employed to use the expert lens to identify management strategies and key performance indicators to build on the SMS project model and develop a decision support system framework for SMS program cost estimation. The Delphi technique accomplished structured communications by providing feedback through participant contributions, analysis of group judgments, and the opportunity for participants to revise their views while maintaining anonymity (Linstone & Turoff, 1975). Data was collected in three rounds using written responses to a questionnaire which participants were asked to respond. Data analysis involved familiarization, identification, indexing, charting, and mapping.

Significance of the Study

Participation in SMS programs in the U.S. remains voluntary; yet, will soon become required by regulation (Čokorilo, 2010). Many research studies have focused on data identified by aviation industry authorities as reactive safety management techniques (Cocklin, 2010; Nazeri, Barbara, De Jong, & Sherry, 2008; Nazeri, Donohue, & Sherry, 2008; Marais & Robichaud, 2012; Plant & Stanton, 2012; Rodrigues de Carvalho, Gomes, Huber, & Vidal, 2009). However, the debate in the safety domain on safety data classification as proactive-reactive and leading-lagging indicators for risk mitigation is ongoing (Groen, Stamatelatos, Dezfuli, & Maggio, 2010; Hopkins, 2009; Kjellen, 2009; Mengolini & Debarberis, 2008; Øien, Utne, & Herrera, 2011; Reiman & Pietikainen, 2012; Sgourou, Katsakiori, Goutsos, & Manatakis, 2010; Wreathall, 2009).

Although the use of business methods were emphasized in SMS guidance material (Chen & Chen, 2012; Čokorilo, 2011; Čokorilo, Mirosavljević, & Gvozdenović, 2011; FAA, 2010; Flouris & Kucukyilmaz, 2009; ICAO, 2009, 2012) the systematic procedures, practices, and policies for SMS program cost estimation to make a significantly strong business case for safety programs was lacking (Brophy, 2009; Johnson, 2010; Lercel et al., 2011; Lu, Young, et al., 2011; Rosenkrans, 2012, Wang et al., 2013). However, the need to make a business case for managing safety issues and practices in the context of occupational safety and health has grown over the past 20 years (Crossman, Crossman, & Lovely, 2009; Jallon et al., 2011; Veltri & Ramsay, 2009). Benefits of this research are multiple and included obtaining theoretical knowledge of the ICAO SMS program model, which in turn may assist decision makers in planning efforts for program designs, assist decision makers in the prevention of project failure through inclusion of identified critical elements, and assist decision makers in reducing financial risk in their respective industrial sectors (Anderson et al., 1994; Lu, Young, et al., 2011). Importantly, if cost aspects of SMS programs implementation are not accurately and comprehensively analyzed, the aviation industry may remain in a stalled progress among aviation sectors neither willing to participate in the development of internationally accepted theoretical frameworks (Flouris & Kucukyilmaz, 2009).

Understanding management strategic and key parameters of SMS programs, specifically costs and benefits of such programs, may help decision makers design SMS programs and obtain true business benefits (Cox & Flouris, 2011). Here the development of a theoretically-founded adaptive model may be ideal (Anderson et al., 1994; Deming, 1986; Lu, Young, et al., 2011). The data derived from the study addressed the need for a management decision-making model for SMS cost estimation that was conceptually grounded in quality management principles (Anderson et al., 1994; Avers et al., 2011; Cox & Flouris, 2011; Deming, 1986; Lu, Young, et al., 2011). Data was collected to identify key factors in the use of a decision support system framework for SMS program cost estimation. The study explored how SMS cost estimates may be modeled using existing information sources to provide decision makers with a framework for SMS program strategies (Lu, Young, et al., 2011). The model may then be applied to an ongoing framework to conduct cost-benefit analysis for safety initiatives and ROI for program implementation with quality and safety management objectives.

Adebiyi, Charles-Owaba, and Waheed (2007) researched different modeling efforts on safety performance evaluation and concluded that the financial implications of safety programs have not been addressed to determine the actual benefits or losses on such an investment. Deming's (1986) quality management principles of leadership, process control and continuous improvement provide the foundation. Both process control and continuous improvement applied in Deming's management method has been linked to higher quality and lower costs (Anderson et al., 1994).

The study incorporates ABC principles (Cooper & Kaplan, 1999) and the theory of quality management as the theoretical framework (Anderson et al. 1994). As a theoretical approach to the study problem, the role of Deming's management method and theory of quality management in academic literature has remained relatively unexplored despite the effect on the practice of management (Anderson et al., 1994), so the study was significant to the current scholarship. According to Anderson et al. (1994), the gap in the literature was due in part to the lack of theory to guide the researcher and postulated the theory of quality management facilitates organizational learning and continuous improvement processes, which must be articulated by organization leaders. Safety professionals have suggested the inclusion of ABC principles to collect financial data as a means to make a business case for safety initiatives (Jallon et al., 2011; Rosenkrans, 2012; Tsai & Hsu, 2008). Management uses information for decision-making related to design and planning quality, customer service, assessment, and continuous improvement (Cooper & Kaplan, 1999). Obtaining knowledge to facilitate organizational learning and continuous improvement processes beyond the boundaries of a single discipline as suggested by some researchers and practitioners (Anderson et al., 1994; Deming, 1986) contributes to scholarly and practitioner literature of theory of quality management and ABC principles to stimulate further discussion and approaches of the management methods.

Definitions

An understanding of the topic was accomplished with reference to various scholarly papers, industry articles, and government documents. Different standards and definitions were noted throughout the literature. The operational definitions of key terms used throughout the study were provided in this section to provide clarity within the context of the study.

Activity-based costing. Activity-based costing is an accounting method that traces all direct and indirect costs of a particular function as a control method for project management (The Chartered Institute of Management Accounting, 2005).

Cost-benefit analysis. A cost-benefit analysis is a quantitative method of assessing the cost of a project or policy and the long-term effects of the program (The Office of Management and Budget [OMB], 1992a). The definition used in this study relate to FAA safety management programs.

Cost estimation. Cost estimation is a quantitative method of assessing the cost of task related to providing a service or manufacturing a product, considering with this the information needs of the stakeholders (Čokorilo, Gvozdenovic, Vasok, & Mirosavljevic, 2010).

Decision support system. A decision support system is a management tool developed by experienced persons and approved by policy makers to be used by others to assist in decision-making activities to increase efficiency (Buryak, Insarov, & Kalinina, 2008). Decision support systems may be written documents in the form of organization policies. For example, in aviation, standard operating procedures and minimum equipment lists are typically provided as a decision support tools for flight and ground crews to evaluate the airworthiness of an aircraft (Atak & Kingma, 2011; Øien, Utne, Tinmannsvik, & Massaiu, 2011; Papakostas, Papachatzakis, Xanthakis, Mourtzis, & Chryssolouris, 2010; Johnson, Kirwan, & Licu, 2009).

Risk. Various standards and frameworks focusing on risk management and associated definitions have been developed (Aven, 2011c). According to Hubbard (2010), risk is defined as "the probability and magnitude of a loss, disaster, or other desirable event" (p. 8) and further explains risk is "a state of uncertainty where some of the possibilities involve a loss, injury, catastrophe, or other undesirable outcome" (p. 80). Much of the literature related to SMS programs refers to risk in the context of loss of equipment or loss of life. For the purpose of this study, loss and undesirable events include financial risk to organizations.

Safety management system (SMS). A safety management system is a formal, top-down business management practices to managing safety and includes the systematic procedures, practices, and policies for the management of safety such as safety risk management, safety policy, safety assurance, and safety promotion (DOT, 2010; ICAO, 2008). For the purpose of this study, a SMS includes the business practices of managing financial costs related to safety management programs.

Summary

Although implementation of SMS programs has been a top priority in the aviation industry, the implementation of voluntary aviation safety programs has remained stalled (Chilester, 2007; FAA, 2010c; Lowe et al., 2012). From the business perspective, the cost of the safety initiatives in the aviation industry has limited SMS program implementation (Avers, Johnson, Banks, & Nei, 2011; Lu, Schreckengast, et al., 2011; Yantiss, 2011). As of September 27, 2010, there were 90 certificated part 121 air carriers (FAA, 2010d). At this time of this study there are 562 part 139 certificated airports (FAA, 2010e), 1,900 part 135 commuter and on-demand operators (FAA, 2012a), and approximately 4,187 domestic and 709 foreign part 145 repair stations (FAA, 2008) certificated by the FAA. As of April 2011, there were 130 participants in SMS pilot studies, many of which were operators and service providers (FAA, 2011c). Financial and administrative burdens are still a concern for managers and many participants reported financial incentives with safety efforts were not effective (FAA, 2011a). In the NPRM (FAA, 2010d), the FAA stated the proposed regulations are modeled after the ICAO frameworks and may be extended to other FAA-regulated entities.

Some managers may have proceeded with SMS program implementation without a complete understanding of the cost effect to their organization (Liou, Yen, & Tzeng, 2008). Safety professional have suggested the inclusion of ABC principles to collect financial data as a means to make a business case for safety initiatives (Jallon et al., 2011; Rosenkrans, 2012; Tsai & Hsu, 2008). The FAA program guidance (DOT, 2010) indicated that costs should be collected; yet, no known empirical studies have identified SMS cost estimation models to identify management strategies and key performance indicators apart from perceived cost benefit in the context of risk mitigation (Lercel et al., 2011; Rosenkrans, 2012).

In Chapter 1, an introduction to the study was provided that introduced the research topic. A descriptive qualitative method was selected to develop a decision support system framework for SMS cost estimation and establish the validity of the initial drivers provided in the ICAO SMS project model. The problem statement with the background of the problem was presented; the purpose of the study documents the intent of the study. The constructs of the study were identified as the degree of relevance and need for inclusion of key factors including (a) business applications (Callaway et al., 2009), (b) labor standards and sources (ASA, 2011; Bernstein, 2007), and (c) schedule standards (Vanhoucke, 2012), for a decision support system framework may be determined by a select group of aviation management experts who possess a broad understanding of project management and project cost analysis.

Finally, the theoretical framework identified the broad area of research to build on the theory of quality management (Anderson et al., 1994) and what research questions the study will answer. The nature of the study provides an explanation of the study design followed by the significance of the study explaining the importance of the study. A list of definitions and key terms used throughout the study was also provided.

Chapter 2: Literature Review

The purpose of the qualitative study was to identify key factors in the use of a decision support system framework for SMS program cost estimation employing a modified Delphi technique to allow for a panel of aviation industry experts to contribute a critical knowledge base to the study. The literature review encompassed a review of documents, articles, books, and scholarly papers related to SMSs, and the chapter was organized by major themes related to SMS programs. The literature review consisted of multiple constructs related to SMS programs and referenced scholarly papers regarding landmark aviation accidents (Englehardt, Sallot, & Springston, 2004; Lucero, Kwang & Pang, 2009; Makamson, 2012); FAA safety initiatives (Layton, 2012; Linhares, 2009); selected analytical frameworks (Harrison & Fan, 2010; Liu & Pan, 2007; Singer & Donoso, 2008) and the respected theories underpinning selected analytical frameworks for accident prevention programs (Levine & Toffel, 2010; Manuele, 2011b; Plant & Stanton, 2012); program management techniques including cost-benefit analysis and cost analysis methodologies (Chen & Chen, 2012; Harrington, Morgenstern, & Nelson, 2009; Gillard, 2009; Lu & Tseng, 2012; Rosenkrans, 2012; Woolston, 2012); and decision support systems (Choo, 2008; Hagos, 2010; Dahl & Derigs, 2011; Lin & Change, 2008; Novak, Paulos, & St. Clair, 2011).

Literature related to organizational systemic problems was also reviewed to understand different approaches to accident prevention (Hovden, Albrechten, & Herrera, 2010; Kontogiannis & Malakis, 2009, 2012; Leveson, 2011; Littlejohn, Margaryan, & Lukic, 2010; Naveh, Katz-Navon, & Stern, 2011), project management (Eldin & Hamza, 2009; Guillerm, Demmou, & Sadou, 2012; Shepherd & Cardon, 2009; Tesch, Sobol, Klein, & Jiang, 2009; Wikstrom, Hellstrom, Artto, Kujala, & Kujala, 2009; Zwikael & Ahn, 2011), and cost estimating efforts (Basti et al. 2010; Čokorilo et al., 2010; Duran, Rodriquez, & Consalter, 2012; Eklin, Arzi, & Shtub, 2009; Lipke, Zwikael, Henderson, & Anbari, 2009; Qian & Ben-Arieh, 2008; Scherbaum, Dschemuchadse, & Kalis, 2008).

The strategy for the literature review focused on recent scholarly sources, peer-reviewed articles, books, and dissertations. Research was conducted using a combination of online databases including ProQuest, SciVerse ScienceDirect, ABI/INFORM Global, Sage Journals, Northcentral University Dissertations, and Google Scholar. In addition, reference sources included peer-reviewed articles provided by industry organizations, professional associations, and government publications. Keywords, phrases, and acronyms used to search databases for relevant literature included: *aviation, safety management system, SMS, decision support system, cost estimation, cost analysis, return-on investment, safety theory, control theory, theory of quality management, program management, program costs, safety culture, Flight Operations Quality Assurance, FOQA, Aviation Safety Reporting System, ASRS, accident, incident,* and *prevention.*

Landmark Aviation Accidents

Two major airline accidents occurred in 1996, one involving ValuJet Flight 592 (Clarke, 2008; Lucero et al., 2009; Makamson, 2010) and the other involving Trans World Airlines (TWA) Flight 800 (Clarke, 2008). Three hundred forty people died, and both aircraft were destroyed (National Transportation Safety Board [NTSB], 2000a, 2000b). The two accidents led to increased concerns among members of the public regarding aviation safety.

According to an NTSB (2006b) report, the probable cause of the ValuJet Flight 592 crash was the actuation of one or more oxygen generators improperly carried as cargo. The report indicated that several management issues contributed to the ValuJet accident. Two other similar incidents involving oxygen generators were noted: a fire that destroyed a DC-10 in 1986 at Chicago O'Hare Airport and an incident involving a DC-9 in 1988 en route to Nashville. Another NTSB (2000a) report indicated the probable cause of the Trans World Airlines Flight 800 crash was an explosion of the center wing fuel tank resulting from the ignition of the flammable fuel-air mixture in the tank. The exact cost of the ValuJet and Trans World Airlines accidents is unknown, but was estimated to exceed $500 million.

After the two major accidents in 1996, representatives of the GAO (1997) reported the need to make aviation safety data more available to the public. Studies related to these two accidents (Clarke, 2008; Siomkos, 2000) focused on contributing factors leading up to the events, commonly known as *lessons learned* (Eisen & Savel, 2009; McDonald, 2009; Murphy & Conner, 2012; Saleh, Marais, Bakolas, & Cowlagi, 2010). Many improvements in aviation have come from analysis of individual accidents (Oster et al., in press). According to Benner and Rimson (2009), current practices in the context of a lesson learned program are "inadequate to take advantage of the opportunities offered by investigated accidents" (p. 72) and explained one ideal attribute included cost sensitivity and value in terms of results of the system. In a survey of responses to the accidents (Global Aviation Information Network, 2001), many respondents stated they used data from accident reports and lessons learned that were available outside their organizations; yet, many people perceived the problems discovered "could not happen here" (p. 3).

FAA Safety Initiatives

Many safety initiatives have been implemented within the aviation industry since the ValuJet and TWA accidents (Layton, 2012). In addition to links to regulatory safety standards (National Archive and Records Administration, 2012), FAA representatives maintain several data collections of accidents, incidents, and other data related to safety (GAO, 2010; Marais & Robichaud, 2012; Nazeri, Barbara, et al., 2008). Analysts may easily access these data collections through the Internet. The FAA also provides data to cross-reference routine business issues such as aircraft registry (Lobo, Hagen, & Whitefield, 2012; Rupp, 2009), repair station information (FAA, 2008), supplemental type certificates (FAA, 2012c), and type certification (FAA, 2012d).

FAA personnel have advocated the implementation of SMS and human factors programs in aviation organizations (Bowen, Sabin, & Patankar, 2011; DOT, 2010). Human factors programs are designed to train the individuals considered the weakest links in aviation (Teperi & Leppänen, 2011). In a study examining the status of human factors programs of aviation companies worldwide, less than 10% of the 414 respondents reported performing a cost-benefit analysis to justify program interventions (Hackworth, Holcomb, Banks, Schroeder, & Johnson, 2007). Representatives of many aviation organizations reported using Maintenance Error Decision Aid or some modification of Maintenance Error Decision Aid or certain modifications of MEDA, the Human Factors Analysis and Classification System (HFACS), or other selected program (Hackworth et al., 2007). Wade (2011) studied accident rates of the U.S. and U.K. to understand if human factor programs reduced the number of maintenance related accidents and found there were no significant difference between maintenance accident rates after human factor regulations were implemented. Wade's (2011) study was notable to the aviation industry because he examined the possibility of unsupported economic burdens of human factor program regulations.

Anfield (2007) explained methods to control human errors using a metaphor 'ignorance iceberg,' one of the first accident causation models (Stoop & Dekker, 2010), to explore who in an organization knows about organizational problems even though the iceberg model was not supported by empirical evidence (Hovenden, Albrechtsen, & Herrera, 2010; Hudson, 2009; Swuste, van Gulijk, & Zwaard, 2010). Accident prevention concepts implement controls before an incident or accident occurs (Bellamy et al., 2009; Flouris & Kucukyilmaz, 2009; Layton, 2012). According to Anfield (2007), the ignorance iceberg is understood as problematic issues taking the shape of an iceberg, and further explained who in an organization are aware of errors.

The quality and safety disciplines are closely related in many fields (Smith, 2011). Anfield's (2007) study was noteworthy because a proactive safety program could use employees as a major resource for safety improvement, which follows the teachings of Deming (1900-1993) and his contributions to theory of quality (Mauléon & Bergman, 2009). Deming has been known as the father of quality and also known for his contribution to Japan, post-World War II, where he taught top managers quality methods (Mauléon & Bergman, 2009; Redmond et al., 2008). The ignorance iceberg supports Deming's teachings in using subject matter experts to solve organizational problems, which was emphasized throughout the quality and safety literature (Grote, 2008; Friend, 2011; Kumar & Balakrishnan, 2011; Seemel, 2011). Literature related to organizational and employee silence (Tangirala & Ramanujam, 2008; Verhezen, 2010; Zikmund, 2003); trust (Covey & Merrill, 2008; Earle, 2010; Park & Kim, 2012; Törner, 2011; Van de Walle & Turoff, 2008; Verhezen, 2010; Wright & Rowe, 2011); and change management (Agboola & Salawu, 2011; Flouris & Kucukyilmaz, 2009; Grote, 2008; Njå & Solberg, 2010; Paulino, 2010) were reviewed to investigate the assumption that 100% of employees are aware of errors and continuous improvement efforts reliance on employees to help identify areas of risk.

A notice of proposed rulemaking (FAA, 2010d) recently proposed by FAA representatives was initiated after Colgan Air, operating as Continental Flight 3407, crashed in Buffalo, New York in 2009 killing 50 people (Smith, Bjerke, NewMeyer, & Niemczyk, 2010; Todd & Thomas, 2012; Wang, 2010; Ward, 2011). Investigations after the crash revealed risks regarding flightcrew fatigue, pilot training standards, safety standards, and other risks to travelers (Caldwell, 2012; Smith et al., 2010; Wang, 2010). The cause of the crash was attributed to pilot error in addition to many people, policies, and practices that were lacking (Diels, Northam, & Peacock, 2009; Smith et al., 2010). In hindsight, underlying systemic problems (Roelen, Lin, & Hale, 2011) and ethical behavior (Buck, 2011) associated with risks accepted by the industry may be linked with economics; however, these links have yet to be empirically studied. In addition, the new law has received considerable opposition due to economic burdens to the industry (Zremski, 2012). Many airlines that balance services with supply and demand have felt the economic impact of external shocks, such as the financial meltdown of 2008, where airline industry profits have been at best only marginal (Adler & Gellman, 2012).

The SMS framework includes state safety policy and objectives, safety risk management, safety assurance, and safety promotion, commonly referred to as the four pillars of safety (DOT, 2010; ICAO, 2009). The SMS is a framework for a state (government) safety program that builds on an acceptable level of safety and systems theory. An acceptable level of safety was not clearly defined in the literature but was understood to be delivered through action plans used as tools in an organization to define system targets or goals that measure reliability (ICAO, 2009). According to Leveson (2011), three potential explanations were identified regarding why many industries continue to have major accidents: "(1) our analysis methods do not discover the underlying causes of events, or (2) learning from experience does not work as it is supposed to do, or (3) learning is happening in the wrong places" (p. 55).

The basis of the risk management component of SMS is a systems safety process model (DOT, 2010). While the literature emphasized the need to use incident-learning systems to improve and analyze the deficiencies in risk systems, some suggest these methods are reactive (Herrera, Nordskag, Myhre, & Halvorsen, 2009). One strategy for risk management is the as-low-as-reasonably-practical (ALARP) principle (Abrahamsen & Asche, 2010; Abrahamsen & Aven, 2008; Aven, 2009; Aven & Hiriart, 2011; Ersdal & Aven, 2008; Flage & Aven, 2009; Mengolini & Debarberis, 2008; Moseman, 2012; Vatn & Aven, 2010; Zhou & Liu, 2012). However, the ALARP principle has proved to be problematic when used to demonstrate the risk of fatality below a predetermined target (Hopkins, 2011). For example, an acceptable level of safety risk to prevent an accident due to maintenance failure is 1E-9 (1 event per 100 million opportunities) (Flouris & Kucukyilmaz, 2009). The ALARP principle was evident in much of the literature (Flage, Coit, Luxhoj, & Aven, 2012; Jones-Lee & Aven, 2011b; Makin & Winder, 2008; Manuele, 2008; Saleh & Pendley, 2012; Turner & Tennant, 2010) related to risk in the context of safety and health of employees at work. The primary focus of system safety is to identify, evaluate, and control safety risk (DOT, 2010). Aven (2012b) and Hubbard (2009) reviewed the cultural theory of risk and presented developmental paths for the risk concept.

Safety Theories

According to some (Lofquist, 2010; Mohaghegh, Kazemi, & Mosleh, 2009; Swuste et al., 2010), the safety science domain lacks specific theories. Several theories were examined to understand the theoretical underpinnings of SMS programs and to examine why SMS programs have not always been implemented in the aviation industry. Theories examined included theories related to leadership (Baba, Tourigny, Wang, & Liu, 2009; Bhattacharya & Tang, 2013; Braman, 2009; Carrillo, 2010; Eid, Mearns, Larsson, Laberg, & Johnson, 2012; Muller & Turner, 2010; Sims, 2009; Törner, 2011; Zohar, 2010), organizational behavior theories (Lundberg, Rollenberg, Hollnagel, & Rankin, 2010; Mohaghegh et al., 2009; Keren, Mills, Freeman, & Shelley, 2009; Reiman & Rollenhagen, 2011), and literature borne from economic theory with regard to time and cost of program management (Askarany, Yazdifar, & Askary, 2010; Flage & Aven, 2009; Vernon, Goldberg, & Golec, 2009).

Heinrich's Accident Pyramid. The ICAO SMS program includes several theoretical frameworks. Of particular interest was Heinrich's Accident Pyramid proposed in 1931 to describe the links between accidents, incidents, near misses, and other safety data (Heinrich, Petersen, & Roos, 1980). According to Heinrich's Accident

Pyramid, also known as Heinrich's Law or Occurrence Pyramid, for every accident that causes a major injury, there are 29 accidents that cause minor injuries and 330 accidents that cause no injuries. According to Corcoran (2004), one empirical finding from the work of Heinrich was that many accidents share common root causes. Although some researchers (Manuele, 2011b; Swuste et al., 2010) have questioned the validity of Heinrich's Law, many understand the concept in relation to mishap prevention (Carrillo, 2010; Korolija & Lundberg, 2010; Nazeri, Donohue, & Sherry, 2008; Smith, 2011).

Dynamics of accident causation (a.k.a., Swiss Cheese theory). Intervention strategies could not be developed in the aviation industry until an analytical framework was developed to help design data-driven safety programs (Li, Harris, & Yu, 2008). In 2000, the dynamics of accident causation theory (Reason, 1990), commonly described using the metaphor 'Swiss Cheese' (Swuste et al., 2010), was introduced to the aviation community as an analytical framework (Shappell & Wiegmann, 2000). An assumption of the dynamics of accident causation is that interventions are placed in defense systems applying control theory (Arminen, Auvinen, & Palukka, 2010; Li et al., 2008; Saleh & Pendley, 2012) to control human errors and correct systemic problems, although control theory was not prevalent in literature discussions of safety (Saleh et al., 2010). Hovden et al. (2010) suggested that a new accident theory is needed. Saleh, Saltmarsh, Favaro, and Brevault (2013) suggest pathology and mathematical frameworks provide a richer path for examining risk and safety issues.

Systems theory. The most effective safety models build on systems theory and include approaches to engineering design, risk assessment techniques, performance monitoring, and safety metrics (Leveson, 2004). Systems theory is a management approach based on communication that models various kinds of information at different organization levels (Leveson, 2011). According to Leveson (2011), using systems thinking and systems theory, safety is viewed as a control problem where safety constraints need to be enforced. Bergeon and Hensley (2009) applied Reason's Swiss cheese model and systems theory to develop a predictive risk mitigation analysis (PRiMA) model. The PRiMA approach assesses existing safety layers, followed by a proposal for strengthening the layers, considers whether new layers could be added, and compares their benefits to the cost of implementing and maintaining them.

Control theory. Literature related to control theory was reviewed since SMSs are seen as a function of management (Roelen et al., 2011), although it was relatively absent from safety literature (Saleh et al., 2010). The concepts of control theory were postulated by some to be important to system safety and accident prevention (Bakolas & Saleh, 2011). Researchers have suggested control theory as a modeling approach for safety management since system safety is a control problem and management is typically seen as a control function (Bakolas & Saleh, 2009; Roelen et al., 2011; Saleh et al., 2010). In addition, quality control theory has been applied to continuous quality improvement programs (Curran & Totten, 2011) and explained by Hudson (2009) as 'bow tie' diagram conventionally used in the engineering discipline. Control theory may be applied to management accounting processes although many theories imported from other disciplines have not been considered unique to the management accounting research community (Malmi & Granlund, 2009).

Intervention theory. Literature (Baard, 2010; Gardner, Whittington, McAteer, Eccles, & Michie, 2010) related to intervention theory was reviewed to understand if the theoretical foundation could be applied to accident prevention and cost estimation models. Intervention theoretical framework was derived from social sciences and the approach has been suggested to promote management accounting research (Baard, 2010). In addition, intervention theory may have to potential to advance knowledge on accident prevention since the theoretical underpinnings are found in control theory (Baard, 2010). Intervention theory may be a theoretical underpinning of continuous improvement methods suggested by the theory of quality management (Anderson et al., 1994).

Predictive, Proactive and Reactive Safety Studies

The literature review included a search for studies and scholarly articles related to aviation SMS programs. In addition, the review included literature related to various management methods of accident prevention in industries other than aviation with a focus on organizational management methods (Aase et al., 2009; Bellamy, Geyer, & Wilkinson, 2008; Chenhall, 2008; Naveh et al., 2011; Wentholt, Rowe, König, Marvin, & Frewer, 2009) and leadership styles (Baba et al., 2009; Sims, 2009; Törner, 2011; von Thaden, Kessel, & Ruengvisesh, 2008). Many researchers and industry professionals disagree on what constitutes aviation safety data or the relationships of common factors that lead to mishaps (FAA, 1997).

Three major databases were the source of data used in many aviation industry studies: (a) the Aviation Accident Database & Synopsis maintained by the NTSB; (b) the AviationDB, also known as the Accident and Incident Database System (AIDS), maintained by the FAA; and (c) the Aviation Safety Reporting System (ASRS), maintained by NASA. The NTSB is the official investigating agency source of aviation accident data in the United States (GAO, 1996). The NTSB's Aviation Accident

Database and Synopses contains over 140,000 collections of aviation accidents (NTSB, 2012). The FAA is responsible for investigating aviation incidents, including potentially hazardous events that do not meet the aircraft damage or personal injury thresholds contained in the NTSB definition of an accident (GAO, 1997). The FAA/AIDS database contains data records for general aviation and commercial air carrier incidents (Marais & Robichaud, 2012). A review performed of the three most common data sources used in aviation studies in the United States, found none of the databases have structured fields (data records) to include the estimated or actual financial costs of undesired events. Other databases used as sources of aviation safety data included the Service Difficulty Reports (SDR) (Marais & Robichaud, 2012) and the Operational Errors and Deviations System (OED), both maintained by the FAA (Nazeri, Barbra, et al., 2008).

Most aviation safety studies focused on analyzing accident and incident data to determine their relationships and how they may be used for error management. Ricci, Panos, Lincoln, Salerno, and Warshauer (2012) postulated the reason for success in error management in aviation industry is due to process standardization. Several studies reported factors contributing to human errors in accident chain of events (Hackworth et al., 2007; Shappell & Wiegmann, 2000, 2009). Many studies evaluated surveillance instruments, classification systems, and different techniques for mining aviation safety data (Nazeri, 2003; Nazeri, Barbara et al., 2008; Nazeri, Donohue, et al., 2008). Most aviation data are available electronically and many databases have not been structured with any classification system to identify accident and incident precursors without extensive analysis (GAO, 2010; Lu et al., 2006; Shappell & Wiegmann, 2000). Ladkin (2002) explained classification is necessary in order to study similarities to learn lessons to apply in the future. Various data mining methods have been researched to overcome the design of data collection systems (Lu et al., 2006; Nazeri, 2003; Nazeri & Bloedorn, 2004; Nazeri, Barbara, et al., 2008). According to Tamuz (2004), the type of data an organization collects and how it classifies data can influence identifying accident precursors. In a study (Ma, 2005) conducted on human factors relating to data mining processes, subject matter experts that analyze safety data were studied to model their individual cogitative task analysis of data mining. Research involving data mining tends to be time consuming and cost prohibitive (Dekker, 2010).

Many researchers have used accident and incident data to discover (or not discover) trends (e.g. Nazeri, 2003, 2007). Lu et al. (2005) studied the practical use of SMS concepts using accident data available in the NTSB database and discovered accident causes (direct hazards) were associated with root factors using Fault Tree Analysis (FTA). Fault Tree Analysis is a common tool used by system safety experts (Ferdous, Khan, Sadiq, Amyotte, & Veitch, 2011; Mohaghegh et al., 2009). Lu et al. (2005) found non-flight errors were the most significant direct hazard to Part 121 operators (airlines) and although the study did not use data available in aviation organizations, the use of computer software for risk analysis was emphasized. Nazeri (2007) concluded there was a relationship between accidents and incidents and recommended further research to fill knowledge gaps.

Even though most aviation professionals agree that accidents are usually the result of several failures of defense processes, at least one common factor (reported as probable cause) was present in 91.5% of all civil aviation accidents and selected incidents reported by the NTSB from 2003 to 2007 (NTSB, 2012). All 9,907 records from 2003 to 2007 include a probable cause, and most records included factors contributing to the event. Direct or indirect costs incurred as a result of the mishap or root causes were typically not reported with these data. Given the way the databases are structured, researchers would need to query each report to identify root causes reported as a probable cause of a safety event. Some researchers disagree on the definition of root cause and that investigators should focus on determining causal structure rather than finding root causes of incidents (Del Frate, Zwart, & Kroes, 2011; Fergencik, 2011). Other researchers believe root cause analysis is the first step necessary to develop effective controls to reduce risk, which have been grounded in QMS programs (Groth, Wang, & Mosleh, 2010; Groen et al., 2010; Maggio, Groen, Hamlin, & Youngblood, 2010).

Many accident investigations lead to the discovery that factors contributing to the accident were known to be a problem before the accident occurred (Hart, 2004; Nazeri, 2007). These factors, also called accident precursors, may not be easily recognized (Groen et al., 2010; Nazeri, 2007; Phimister, Bier, & Kunreuther, 2004; Saleh et al., 2013). According to Carroll (2004), precursors are signals of possible problems, and every precursor event is, therefore, both a test of the adequacy of system defenses and an opportunity to develop and apply knowledge to avoid accidents. A failure to recognize accident precursors may be due in part to the quality of safety data, particularly in how the data have been reported, collected, and stored (GAO, 2010; Lu et al, 2006; Schmidt, Lawson, & Figlock, 2003; Shappell & Wiegmann, 2000). In a study (Olsen, 2013) of 27 papers related to coding techniques of safety data, only one paper (5%) was for proactive use by analysts and five papers (25%) were for both proactive and reactive use. In contrast, Groen et al. (2010) suggested that there will always be a need to elicit expert knowledge to screen potential accident precursors.

Quality Management Systems

Present views on management systems no longer separate quality and safety management systems (Rollenhagen, 2010; Rollenhagen & Wahlström, 2007). The cornerstone for SMS program design began with Quality Management Systems (QMS) concepts (Mizutani, 2010). With the advances of information technology (IT), the influence of quality management on knowledge creation and quality improvement efforts have recently received scholarly attention (Carey & Stefos, 2011; Shan, Zhao, & Hua, 2013). Literature related to management systems were reviewed to understand the business benefits of such programs (Levine & Toffel, 2010; Moosa, Sajid, Khan, & Mughal, 2010; Slatten, Guidry, & Austin, 2011; Thomas, 2012) and the structure and difficulties with management systems (Kumar & Balakrishnan, 2011; Montiel, Husted, & Christmann, 2012; Rezaei, Celik, & Baalousha, 2011; Sharma & Gadenne, 2010).

Management systems play an important role in managing risks, particularly to identify organizational problems, risk mitigation, and correcting issues by implementing preventive and corrective actions (Rollenhagen & Wahlström, 2007; Santos Mendes, & Barbosa, 2011). Quality management systems focus on standards designed to control company procedures, continuous improvement, and ensure consistent quality of the service or product (Psomas & Fotopoulos, 2009; Rezaei et al., 2011; Yantiss, 2011). However, many companies obtained certification with the only intention to be eligible to enter tenders and may not have understood the numerous business advantages (Rezaei et al, 2011; Santos et al., 2011; Slatten et al., 2011). International Organization for

Standardization (ISO) 9000 series is an example of management system standards accepted worldwide with over one million organizations certified (Heras-Saizarbitoria & Boiral, 2013). In a study (Kumar & Balakrishnan, 2011) examining the failure of ISO certified organizations, common problems and system gaps were noted with issues related to leadership, strategy, quality system, and social responsibility. Clegg et al. (2010) postulated most of the critical success factors for quality management practices are understood; however, many quality tools are not understood or implemented well.

The QMS of an organization is designed with several subprograms, many of which are often considered independent programs not under the QMS framework (Bernardo, Casadesús, Karapetrovic, & Heras, 2009; Karapetrovic & Casadesús, 2009; Santos et al. 2011). For example, SMS builds on the framework of QMS but is a subprogram of the QMS of an organization. In a study (Sampaio, Saraiva, & Domingues, 2012) that examined different management systems, the advantages of integrating different subsystems such as environment, safety, and risk, to name a few, supported an integrated approach and "avoided the development of organizational 'islands' related to each subsystem" (p. 418). Safety management programs are designed to emphasize risk management techniques to reduce the possibility of harm to persons or property damage and to maintain the possibility at or below an acceptable level (ICAO, 2009). This reduced harm level is then maintained continually by means of hazard identification and risk management (ICAO, 2009).

There are many different systems in the aviation industry designed to ensure safety (Hsiao, Drury, Wu, & Paquet, 2013). Hsiao et al. developed a model to validate safety audit tools as predictors of safety performance. In part one of the study, 1,238 audit reports from one civil aviation authority were analyzed by four graduate students in the human factors field using a modified taxonomy named Human Factors Analysis and Classification System- Maintenance Audit (HFACS-MA). Hsiao et al. applied theories of management functions to classify activities in HFACS-MA for management into four groups: (a) operations/procedures (planning/organizing), (b) execution (leading/coordinating), (c) resource management (budget/staff), and (d) safety oversight (controlling/correcting). The authors found many audit reports lacked details of root cause, particularly organizational issues, beyond the first-line employee. However, they concluded the results showed significant reliability to proceed with part two of the study which will consist of prediction validity testing to develop a forecasting model to predict the safety performance of maintenance systems.

Process improvement programs, is another subprogram of a QMS and typically involve the collection of data reported by employees directly involved in the process and address organizational or systemic problems. Research related to intervention theory may be an approach to make a difference in organizations involving stakeholders who are experiencing the problem (Baard, 2010). Employees responsible for the oversight, or enforcement, of organizational policies provide audit data and are directly involved in QMS processes. Some researchers have recognized the role of maintenance specialists in high reliability organizations because these specialists are usually the first to notice problems that can trigger other events (Weick, Sutcliffe, & Obstfeld, 1999). Airline representatives, as well as regulatory agencies typically provide safety oversight by performing auditing processes typical of QMS programs (Downer, 2011; Flouris & Kucukyilmaz, 2009).

In a study (Bernardo et al., 2009) of management systems, many standards (i.e., quality, environmental, safety) were based on the Plan-Do-Check-Act (PDCA) model. The Shewhart's cycle is commonly known as the Plan-Do-Check-Act (PDCA) or Plan-Do-Study-Act (PDSA) model (Andersen et al., 1994; Mauléon & Bergman, 2009; Schroeder, Linderman, Liedtke, & Choo, 2008; Sujan, 2012). Integration of the PDCA model in QMS and SMS methods for continuous improvement was emphasized throughout the literature (Alonso-Ameida & Rodriguez-Anton, 2011; Grote, 2012; Knouse et al., 2009; Kumar & Balakrishnan, 2011). The theory of quality management theoretical contribution of this study specifically emphasized the planning steps of the PDCA model imbedded in QMS standards and SMS guidance literature.

Kim, Kumar, and Kumar (2012) examined the relationship between quality management practices and different types of innovation and found quality management practices were directly or indirectly associated with innovation in organizations. A sample of 223 manufacturing and service firms in Canada that were ISO 9001 certified participated in the study. Five types of innovation included: (a) radical product, (b) radical process, (c) incremental product, (d) incremental process, and (e) administrative. Administrative innovation was referred to the application of new innovations that improved organization structures or systems and involve significant implementation costs, organizational disruption, and work activities. Kim et al. postulated that quality management practices aids in facilitating creative problem solving.

The adoption of quality management practices such as Total Quality Management (TQM) and ISO 9000 emphasize benefits that improve efficiency and profitability (Benner & Veloso, 2008). Benner and Veloso examined the effects of adapting quality management practices in the auto industry. Financial data from 75 firms consisted of COMPUSTAT from the period between 1988 and 1997 and included the accounting measures of return on assets (ROA) and return on sales (ROS) along with a stock market measure (Tobin's q). The Tobin's q is a common measure of a firm's value and is defined as the ratio between market value of a firm and the replacement cost of its assets (Malighetti, Meoli, Paleari, & Redondi, 2011). Data on ISO 9000 certifications was obtained from McGraw Hill's database and was measured with binary variables. In addition, successive values were applied after certification was obtained to identify significant trends. Data related to firm technology coherence was also collected. The results of the study found late adaptors of ISO 9000 did not gain financial benefits. However, other research (Din et al., 2011; Levine & Toffel, 2010) found evidence of improved project management, safety, and financial performance of ISO 9000 adaptors versus non-adaptors.

An emerging approach to quality management to improve business outcomes in many industries is six sigma (Curran & Totten, 2011; Pande & Holpp, 2002; Rohini & Mallikarjun, 2011; Zu, Fredendall, & Douglas, 2008). According to Schroeder et al., (2008), six sigma is an organizational learning process patterned after the PDCA cycle (Shewhart, 1931) and DMAIC (define, measure, analyze, improve, and control) model to provide a methodology to solve problems and improve processes. Schroeder et al. used the grounded theory approach to propose a definition and theory of six sigma and postulated the six sigma methodology can be used to establish links between improvement projects and financial performance. In contrast, limitations and suitable applications for the DMAIC method were identified by de Mast and Lokkerbol (2012) that compared the DMAIC method with insights from scientific theories. The most prominent limitation of six sigma being the inferior methodology for efficient problem solving (de Mast & Lokkerbol, 2012).

Accidents and incidents are events that have happened causing injury to individuals or damage to equipment (49 CFR § 830). In addition to the study of mishaps, there is a need to study events in which no mishap has occurred (Groen et al., 2010; Hart, 2004; Lofquist, 2010). These data are commonly stored in QMS programs (or subprograms of a QMS) and are reported by personnel as personal errors, mechanical system failures, inadequate process controls, or non-compliance of established policies. Some researchers and practitioners (Cacciabue & Vella, 2010; Corcoran, 2004; Stolzer et al., 2010) postulated QMS data has the potential to provide trend indicators before a mishap occurs. For example, data collected in the NASA ASRS has the potential to provide trend indicators before a mishap occurs (Suzuki, von Thadon, & Geibel, 2008). Organization mishap data are typically collected in QMS or SMS programs to learn causes of the mishap and recommend corrective actions (Lu, Wetmore, & Przetak, 2006; Santos et al., 2011; Santos et al., 2013). Relatively little is known about relationships between accidents and incidents, or unsafe acts and processes that may be reported in QMS programs such as internal audits and process improvement data (FAA, 1997). Boeing's MEDA concepts are similar to process improvement concepts which have been reported to show significant cost savings and have been used to enhance data collection methods (Johnson, 2010; Liang, Lin, Hwang, Wang, & Patterson, 2010; UKCAA, 2009).

Investigators typically understand the connections between QMS data and mishap data after a mishap event has occurred (Antonsen, Almklov, & Fenstad, 2008).

Researchers and practitioners typically refer to this type of knowledge influenced by hindsight bias (Cedergren & Petersen, 2011; Dekker, 2009b; Reiman & Rollenhagen; Skogdalen & Vinnem, 2012; Steen & Aven, 2011; Schoemaker & Day, 2009; Stockholm, 2010). Researchers have found that many contributing factors discovered in mishap data were known to be a problem in the organization (Hart, 2004; Lu et al., 2006; Nazeri, 2007), but no research literature was located which identified research studies conducted using the QMS program data of an organization to identify accident predictors.

Line Operational Safety Audits (LOSA) is an emerging method advocated to collect safety data (Hale & Borys, 2013; Fogarty & Buikstra, 2008; Ma, Pedigo, Blackwell, Gildea, Holcomb, & Hackworth, 2011). However, audit concepts were evident in the literature related to management systems as early as the 1950's (Deming, 1986; Juran, 1995). Auditing helps identify gaps between current and desired performance, which leads to the development of plans to improve performance (Costello, Saurin, & de Macedo Guimaraes, 2009). In contrast, behavior changes can occur during audit processes of observed tasks and then return to normal afterwards (Mearns, Kirwan, Reader, Jackson, Kennedy, & Gordon, 2013) which can easily skew data. Data collected within management systems are typically designed to help identify systemic problems in the context of inspection and auditing (Bellamy et al., 2008). However, the data may not be recognized as accident predictors. According to Tatikonda and Tatikonda (1996), only a small number of managers really measure the results of quality improvement programs. Antonsen et al. (2008) postulated the failure of personnel to perform tasks required by formal work procedures represented a problem for safety management and traditional approaches to address the problem have found no solution.

Data related to nonconforming products are typically examined to implement corrective actions and understand root causes (Frate et al., 2011; Groen et al., 2010; Vassilakis & Besseris, 2009). *Lean manufacturing*, or *lean production* (also known as *lean*), is a practice typically used in production that considers expenditures for nonconforming products wasteful (Hofer, Eroglu, & Hofer, 2012; León & Farris, 2011; Main, Taubitz, & Wood, 2008; Parry, Mills, & Yurner, 2010; Taneva, Grote, Easty & Plattner, 2010). Lean manufacturing is management philosophy derived from the Toyota Production System influenced by quality leaders such as Juran and Deming in the 1950s (Chenhall, 2008).

Figure 1 is an interpretive illustration of the SMS safety concept from the quality management perspective with reference to literature related to the theory of quality management and risk management concepts in the context of weak signals (Brooker, 2011; Groen et al., 2010; Groth et al., 2010; Konstandinidou, Nivolianitou, Kefalogianni, & Caroni, 2011; Levine & Toffel, 2010; Lofquist, 2010; Schoemaker & Day, 2009). Figure 1 builds on the theory of quality management (Andersen et al., 1994) and the dynamics of accident causation (Reason, 1990), taking into account audits and interventions applying control theory (Gardner et al, 2010; Roelen et al., 2011; Saleh et al., 2010, 2012) and accessible safety information for risk management, as suggested by others (Brooker, 2011; Cacciabue & Vella, 2010). The theory of quality management (Anderson et al., 1994) suggested organizational learning encompasses two types of knowledge: (a) process task knowledge and (b) profound knowledge (Anderson et al., 1994; Deming, 1986) comprising of foundational knowledge which includes system theory, statistics, psychology, and knowledge of theories. Profound knowledge is needed to understand the links of precursors in accident prevention programs as called for by many researchers and practitioners in various domains (Øien, Utne, & Herrera, 2011; Phimister et al., 2004; Saleh & Pendley, 2012; Tamuz, 2004; Teperi & & Leppänen, 2010).

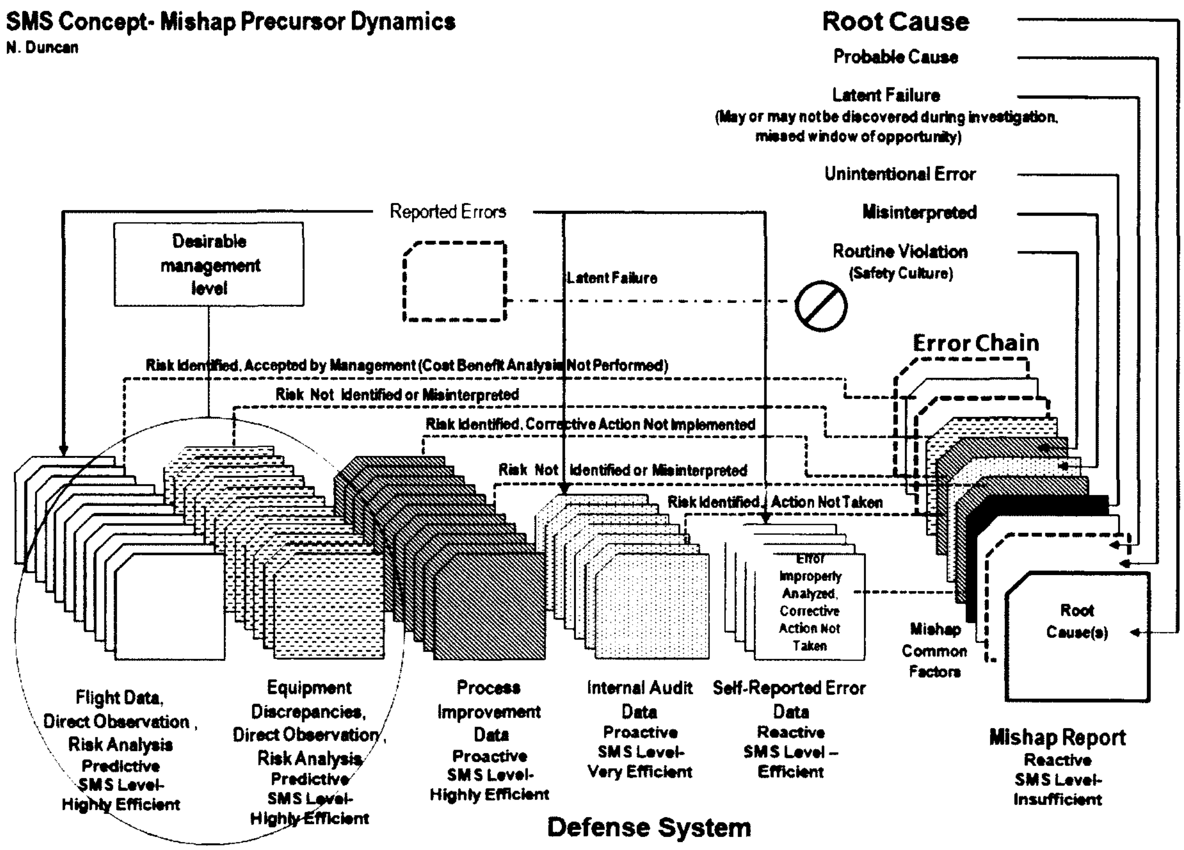


Figure 1. SMS concept of different data sets available to link precursors in defense system data available in QMS programs to help control mishaps. Contributing factors evident in various data sets before a mishap event occurs are illustrated. Adapted from "Notes for a lecture on safety management systems: Proactive and predictive concepts," by N. Duncan (2011), unpublished paper.

Figure 1 depicts mishap precursor dynamics by illustrating a hypothetical mishap investigation report and the root cause (or causes) and common factors that would be discovered during a mishap investigation. Root causes and common factors are illustrated as files and coded to indicate the possible links in other data sets such as flight operational quality assurance (Ananda & Kumar, 2009; Avers et al., 2011; Logan, 2008), direct observation (e.g., equipment discrepancies) (Maggio et al., 2010), process and continuous improvement (Liang et al., 2010; Naveh et al., 2011; Rankin, Hibit, Allen, Sargent, 2000), external and internal audits (Cacciabue & Vella, 2010; Downer, 2011; Fernández-Muñiz et al., 2012a, 2012b), and self-reported errors, commonly known as an Aviation Safety Action Program (ASAP) (Clark, 2010; Hobbs & Kanki, 2008; Lattanzio, Patankar, & Kanki, 2008; Lu et al., 2006) as noted in the literature. Each program data set is represented by other files that could be located (preferably in a computer program module) in a particular system where defense system shortcomings may exist. Both qualitative and quantitative data would be collected for managers to recognize mishap potential easily. The dotted lines from the defense system data represent the links of typical QMS data of aviation organizations to a mishap report, with possible identification and corrective action scenarios. The coding of files for the defense system programs corresponds to contributing factors shown to be evident in some data sets during accident investigation procedures (Körvers & Sonnemans, 2008; Leveson, 2011; Nazeri et al., 2008). The theory of quality management (Andersen et al., 1994) and the profound knowledge of theories (Deming, 1986) contributed by researchers and practitioners, such as normal accident theory (Perrow, 1999); control theory (Gardner et al., 2010; Roelen et al., 2011), evidence theory (Aven, 2011a; Aven & Zio; 2011; Ferdous et al., 2011), and intervention theory (Baard, 2010; Gardner et al., 2010) may be used to investigate links between data available in QMS programs and accident data to further theories in the safety science domain.

Project Management

Discrepancies regarding how SMS is taught and used in the aviation industry have slowed discovery of positive effects of SMS programs (Galotti, Rao, & Maurino, 2006; Hsu, Li, & Chen, 2010). The definition of program management and project management was ambiguous throughout the literature. Artto, Martinsuo, Gemunden, and Murtoaro (2009) researched various sources to explain the differences between project management and program management. The review of literature that related to project management emphasized six themes: (a) project control techniques (Bryde, 2008, Chen & Chen, 2012; Din, Abd-Hamid, & Bryde, 2011; Najmi, Ehsani, Sharbatoghlie, & Saidi-Mehrabad, 2009) (b) cost-benefit analysis (Friend, 2011; Karagiannaki, Pramatari, & Kehagia, 2009; Komarniski, 2011); (c) project costs (Gillard, 2009; Ginieis, Rebull, & Planas, 2012; Hackworth et al., 2007; Irani, 2010; Lercel et al., 2011; Jørgensen, Halkjelsvik, & Kitchenham, 2012; Tari, 2011); (d) cost analysis sources and methodologies (ASA, 2011; Australian Government Bureau of Transport and Regional Economics, 2006; Bureau of Labor Statistics [BLS], 2012a, 2012b; Michell & Braithwaite, 2009; Woolston, 2012); and (e) ROI (Allen, Rankin, & Sargent, 1999; Gorjidooz & Vasigh, 2010; Lercel et al., 2011). The themes were important to the literature review to understand why leaders in the airline industry have been slow to implement SMS programs.

Project control techniques. Research projects are typically defined by success factors such as time, cost, and quality (Din et al., 2011; Najmi, Ehsani, Sharbatoghlie, & Saidi-Mehrabad, 2009); however, the project manager has the responsibility to meet the customer's defined success criteria (Bryde, 2008; Phillips et al., 2012). Although the global trend for organizational leaders to develop and implement SMS programs was clearly evident in the literature (Chen & Chen, 2012; Čokorilo et al., 2010; Čokorilo et al., 2011; Flouris & Kucukyilmaz, 2009; Lu, Young, et al., 2011), empirical evidence of the benefits of SMS (success criteria in the context of cost-benefit) programs was not, other than the perceived benefits to society in the context linked to aircraft accidents. According to Thomas (2012), much of the SMS literature across multiple industries claim benefits of SMS but have not been supported by empirical evidence.

Hsu et al. (2010) discussed characteristics of SMS in the context of project management. The study included a three-step procedure to identify key components of an SMS. First, a Grey Relational Analysis (GRA) was conducted to group key components of a SMS using guidance data from ICAO and four aviation authorities worldwide. Then, a Decision Making Trail Evaluation Laboratory (DEMATEL) process and an Analytic Network Process (ANP) were conducted to map critical components so that a quantitative measurement model could be constructed. The findings weighted the relative importance of key components of SMS. The authors postulated the need to identify the critical components within an SMS so that safety activities would be more efficient for implementation and inspection.

According to Chen and Chen (2012), various degrees of SMS implementation are in practice, while SMS performance measures (program success criteria) have not been identified. In a study (Hsu, Su, Kao, Shu, Lin, & Tseng, 2012) examining the safety performance of a company in Taiwan from the business perspective, inter-related factors were found to be best for safety performance. In general, the authors of the study purported performance measures should be based on the cost effectiveness of interventions combined with risk assessments. In addition, conflicts can emerge at the organizational level when goals such as cost, safety, or productivity are incompatible (Colley, Lincolne, & Neal, 2013; Reason, 1997). Vanhoucke (2012) studied the project control measurements; however, Vanhoucke's study design did not focus on the prediction or control of costs. Chen and Chen (2012) developed an evaluation instrument that measured five factors in SMS programs (a) safety management policy, (b) executive management commitment, (c) documentation and commands, (d) safety promotion and training, and (d) emergency preparedness and response plan. Survey data was obtained from 169 participants from five Taiwan airlines with the majority of the participants holding positions as line managers (74%). Chen and Chen noted that safety oversight and audit dimensions of SMS were excluded by the exploratory factor analysis of the study, despite the emphasis in SMS guidance literature, since the dimensions are regarded as typical operations based on existing civil laws.

Hsu et al. (2010) developed a quantitative evaluation model that identified key components of an SMS. While the model does include quality concepts and strategic timelines, it did not include key project constraints such as cost, which is an important factor for decision makers. Lessons learned were reported after SMS pilot studies (Transportation Research Board [TRB], 2012) were conducted with managers of 26 airports (response rate of 84%). Although the pilot studies were sponsored by the FAA via research grants and the studies were overseen by a committee of the Airport Cooperative Research Program, no quantifiable SMS implementation costs were reported by any of the airports. Funding for the airport SMS pilot studies ranged from $67K to $500K, however, not all airports pursued funding (TRB, 2012). According to King

(2007), the impact of the total ownership cost of a product in the aerospace industry can be grouped into four categories: (a) the costs of research and development; (b) procurement; (c) operation, maintenance and support; (d) and system disposal. In an informal case study (Obi, 2010), factors such as labor time and cost of materials were used to provide simplified methods to estimate manufacturing production costs for engineering students.

Project managers usually organize project schedules to identify goals, milestones, and target dates (Choi & Kwak, 2012; Marques, Gourc, & Laurus, 2011; Zu et al., 2008). A major contributor to scientific management was Henry L. Gantt (1861-1919) who developed a system for precision task management and scheduling (Wilson, 2003). Gantt charts are aids used in project management, with the two most common being the schedule chart, which organizes the intended use of resources in a time period, and the load chart, which shows loading and idling time. Although Gantt charts date back over a century they are popular project management tools, largely due to advances in computer programs (Wilson, 2003). A Gantt chart was provided in the ICAO SMS program model (ICAO, 2009) to identify task-specific activities in the form of a work breakdown structure, which was emphasized in the project management literature (Phillips et al., 2012; Stolzer et al., 2011; Trivailo et al., 2012), and was used in this study. Gantt charts are the cornerstone of effective project planning and management, and have been commonly used in business to track project status with the primary focus on schedules and resources (Chenhall, 2008; Phillips et al., 2012). An example of a Gantt chart that identifies tasks that must be accomplished in a SMS implementation plan is provided in Figure 2.

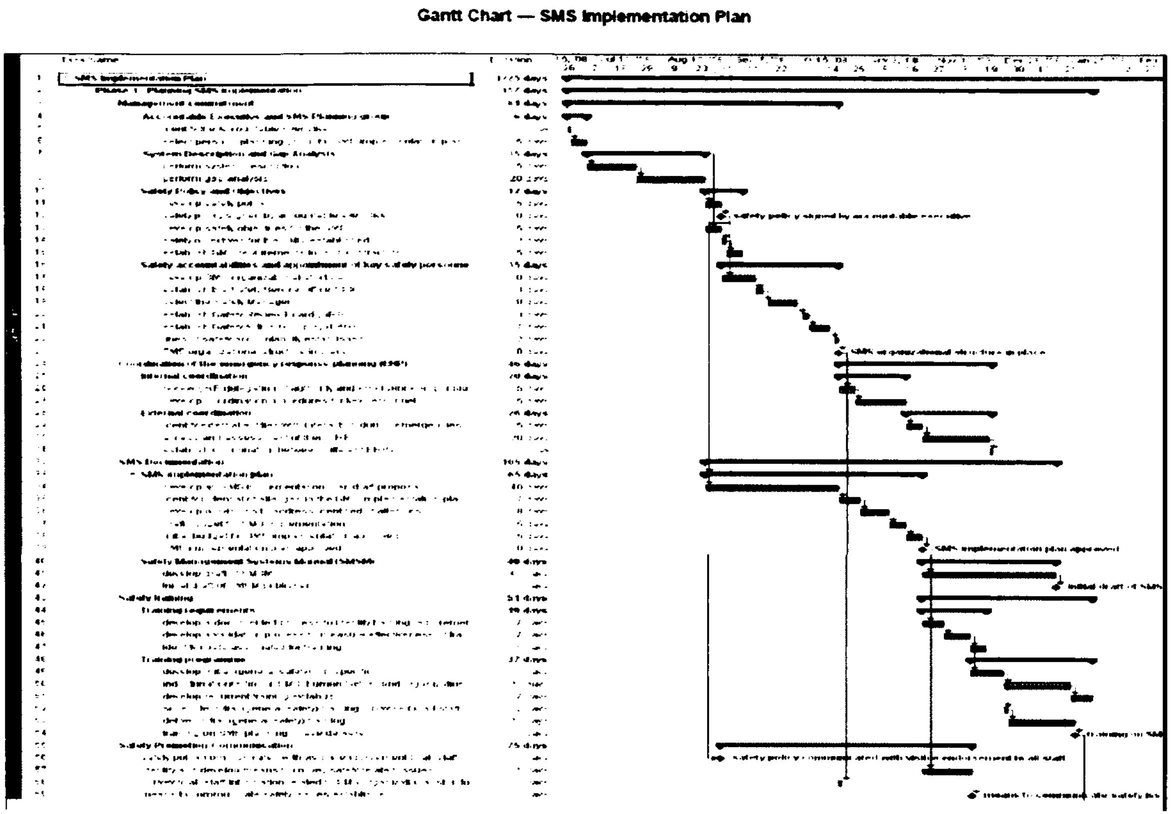


Figure 2. Gantt chart- SMS implementation plan. Reprinted from "Safety management manual (SMM)" by International Civil Aviation Organization, 2009, (Doc 9859), 2nd edition, p. 10-APP 2-11. Copyright 2009 by International Civil Aviation Organization. Reprinted with permission (see Appendix A).

The literature review included a review of the factors that could affect project schedules (Stathis, 1999; BLS, 2011) and the methods for estimating (Mochal, 2006) and controlling (Vanhoucke, 2012) project schedules. Marques et al. (2010) postulated in some cases the Iron Triangle (time, cost, and quality) are insufficient for controlling project performance and emphasized different key performance indicators (KPI) should be included in project measures focusing on different stakeholder's interest. In a study related to project schedules, the BLS (2012) reported the average hours per day working for both men and women was 7.6 hours. Mochal postulated hours per working day were a factor for estimating project duration and explained an average productive work day was equivalent to 6.5 hours. Project management methodology should include other control methods to manage time, cost, and performance (Stolzer et al., 2011). The Project Management Body of Knowledge (PMBOK) was one source that identified acceptable project management standards (Phillips et al., 2012).

Cost analysis. According to Sewell and Marczak (1997), cost analyses provide three main advantages: (a) they help set priorities when resources are limited, (b) they promote financially accountability, and (c) they help decision makers to decide the feasibility to invest in programs. The fundamental reason for most cost analysis is to prevent bad investment decisions; however, program effectiveness is not a guarantee that a program is cost effective or feasible (Sewell & Marczak, 1996). For example, several organizations have invested in SMS program implementation at a cost of over $1 million with no quantifiable ROI (Komarniski, 2011). In a study (Lu, Schreckengast, et al., 2011) conducted at Purdue University Airport for a SMS application, a prototype for a low-cost SMS was developed with a minimum budget. The researchers applied Action Research methodology known as Look-Think-Act loops. Lu, Schreckengast, et al. created a low-cost SMS application for small airports and they suggested further research was needed to investigate unsolved concerns from the aviation industry such as staffing, inexpensive alternations, the lack of cost-benefit analysis, and risk models, to name a few; however, the financial impact of the application of the low-cost SMS was not reported.

Wang et al. (2013) studied the impact of financial condition of airlines and safety investment on the susceptibility to accident risk. In their study, safety investment was quantified in the context of maintenance and training expenditures. Data related to costs were drawn from the Bureau of Transportation Statistics (BTS) financial schedules. Given the importance of safety in the aviation industry, Wang et al. found the lack of cost data suggested a systemic deficiency in the industry and postulated that financial influence of safety investments are not being monitored or adequately studied.

The BLS collects data on different industries and labor categories and introduced the North American Industry Classification System (NAICS) classification system in 1997, which serves as a classification standard for Canada, Mexico, and the U.S. (Duns and Bradstreet, 2012). The NAICS classification system replaced the industrial classification codes (SIC) developed by the Federal Government and business communities. Huang et al. (2009) used the NAICS codes and titles to categorize industry sectors, none of which were specifically identified as aviation; however, 23% of the respondents were involved in manufacturing, which can be compared to some aviation sectors. Huang et al. posited that safety professionals need to understand financial losses in order to demonstrate financial benefits and found the "average perceived return on safety investments was $4.41 (*SD* = 12.0)" (p. 39) for every $1 spent on investment. Another source of financial data was the U.S. Bureau of Transportation Statistics, which collects data on all air carriers in the form of Air Carrier Financial Reports (Form 41) (Gmjidooz & Vasigh, 2010).

Adebiyi et al. (2007) researched different modeling efforts on safety performance evaluation and concluded that the financial implications of safety programs have not been addressed to determine the actual benefits or losses on such an investment. In addition, researchers in the aviation industry advocated the need to "collect more event data and incur more cost" (Wong & Yeh, 2007, p. 50). In contrast, much debate has focused on whether cost information should be used in regulatory decision-making (Harrington et al., 2009).

According to the NPRM (FAA, 2010d), SMS cost range depends on the size of the carrier and the type of operations that they provide. The FAA authorities estimated that for a small carrier, with less than nine aircraft, compliance would cost $253,500 per year for the first three years ($760,500) and then roughly $233,000 per year for subsequent years. For medium sized carriers that have 10 to 49 aircraft, but still have less than 1,500 employees, FAA authorities estimated compliance cost would be $342,450 per carrier per year for the first 3 years and then approximately $222,500 each year thereafter. In contrast, according to representatives of the Australian Civil Aviation Safety Authority (CASA), the cost of developing an SMS was estimated to range between $20,000 to $30,000 for small and medium-sized airlines with an annual operating cost estimated to be between $15,000 and $17,000 (CASA, 2012).

Many states have issued SMS guidance materials in the form of Advisory Circulars (AC). Advisory Circular 120-92 was introduced in the U.S. by FAA authorities in 2006 that provided a framework for SMS (FAA, 2006; Hsu et al., 2010; Lu et al., 2011; Mizutani, 2010), which was revised in 2010 (DOT, 2010). A review of the 2006 version of AC 120-92 listed perceived business benefits of SMS but did not reference any specific empirical studies. The 2010 version of the guidance material did not explain any benefits or cost impact to the industry. Advisory Circulars are not regulatory in the U.S.; however, regulations may be necessary to reverse accident trends, particularity in the helicopter emergency medical services sector (Hsu et al., 2010; MacDonald, 2010).

Cost-benefit analysis. Project managers often use cost-benefit analysis to evaluate the desirability of projects for decision makers (Aven, 2009; Garber & Phelps, 2008). According to Wang, Xie, Chin, & Fu (2013), the purpose of cost-benefit analysis is to compare costs with the benefits of implementing safety measures. Čokorilo et al. (2010) analyzed a risk assessment tool in the context of SMS based on a cost-benefit analysis expressed as an increase or reduction of accident probability with costs categories associated with aircraft hull loss or damage, accident investigation, the statistical value of loss of life, and loss of reputation, to name a few. The study included historical accident data (9 fatalities) and incident data (12) from 1947 to 2005 and forecasted traffic growth data from 2003 to 2010 of the Republic of Serbia. The accident rate for the observed period from 1947 to 2005 was calculated to be 0.78 (incident data was included in the calculation), which confirmed the pattern of accidents can be treated as a Poisson sequence or process where future events do not depend on the number or time intervals of previous events. An example of an A320 aircraft accident suggested the minimum financial costs of the sample were determined to be a function of aircraft age and ranged from 34 million € (Euro dollars equivalent to US $44.1 million) to 380 million € (Euro dollars equivalent to US $493.2 million). Other noteworthy information provided in the study was the alarming accident rate of 0.78 of the Republic of Serbia (see Layton, 2012 for addition insight to other national accident rates). Although, Čokorilo et al. (2010) postulated the cost-benefit analysis must balance accident probability with costs associated with safety improvement measures, no cost data related to the SMS implementation functions were provided if no accidents were to occur.

Some safety management measures are associated with cost-benefit analysis (Mitchell & Braithwaite, 2008). Measures have been based on societies' willingness-to-pay (WTP) principle (Kniesner, Viscusi, & Ziliak, 2010; Mitchell & Braithwaite, 2008) or human capital approach (Australian Government Bureau of Transport and Regional Economics, 2006). The WTP approach examines the cost society is willing to pay in order to save a life (Stewart & Mueller, 2008). The human capital approach uses the value of a person's productive output over their working life (BTRE, 2006). However, differences in societies' WTP and willingness-to-accept (WTA) benefit values remain unexplained (Viscusi & Huber, 2012).

The value of statistical life (VSL) has been used in economic and legal literature as the compromise of the financial cost and the risk of death (Viscusi, 2008; 2010; Viscusi & Huber, 2012, Zajac, 2012). Kniesner et al. (2010) found that the reasonable average cost per expected life in safety and health regulations was US $7 million to US $8 million per life saved but the VSL varied. The FAA regulations value of a life is US $6.2 million, which is based on studies of wage premiums people receive for performing risky jobs (Zajac, 2012).

Stewart and Mueller (2008, in press) conducted assessments of the costs and benefits of air carrier security to prevent an attack similar to the 9/11 events. In one study (Stewart & Mueller, in press), three measures were analyzed: (a) installed physical secondary barriers (IPSB) such as strengthening of cockpit doors, (b) Federal Air Marshal Service (FAMS) program, and the (c) Federal Flight Deck Officer (FFPO) program which allows flight crew members to carry firearms in order to protect the flight deck. In an earlier study (Stewart & Mueller, 2008) that assessed the air marshal program, the annual cost of the program was determined to be US $180 million per life saved but the air marshal program failed the cost-benefit analysis surpassing the regulatory goal of US $1-10 million. The effectiveness of the air marshal program was determined to cost US $1.2 billion per year (Stewart & Mueller, 2008, in press). However, Stewart and Mueller (2008) cost-benefit analysis found risk mitigation actions such as strengthening the cockpit doors was cost effective.

As previously discussed in Chapter 1, FAA (2010d) representatives estimated that the total benefits for SMS programs are $1,143.1 million. The benefits and costs estimated for the 20-year period from 2012 to 2031 are indicated in Table 1. As of September 27, 2010, there were 90 certificate holders conducting part 121 operations that are affected by the notice of proposed rulemaking (FAA, 2010d). The cost estimates provided by the FAA NPRM are equivalent to an average annual benefit for all part 121 carriers of $57.2 million ($1,143.1M ÷ 20) and the average annual cost estimates were $35.5 million ($710.8M ÷ 20). For each part 121 carrier, the estimated annual benefits for part 121 carrier equates to an average of $635,555 thousand ($57.2M ÷ 90) with an average cost of $394,444 thousand ($35.5M ÷ 90).

The data presented in the NPRM (FAA, 2010d) included benefits and costs for 90 air carriers in the U.S. In Table 2, the cost and benefit data from Table 1 was divided by the total number of Part 121 air carriers (*n* = 90) to understand the benefits and cost estimation evident in the NPRM for only one Part 121 carrier.

Table 1

Total Benefits and Costs Per Year for All Part 121 Carriers (in millions of dollars)

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Benefits	$0.0	$0.0	$0.0	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2
Present Value	$0.0	$0.0	$0.0	$47.9	$44.8	$41.9	$39.1	$36.6	$34.2	$31.9	$29.9
Costs	$56.3	$56.3	$56.3	$33.2	$30.4	$33.2	$30.4	$33.2	$30.4	$33.2	$30.4
Present Value	$49.2	$45.9	$42.9	$23.7	$20.3	$20.7	$17.7	$18.0	$15.5	$15.8	$13.5
Year	2023	2024	2025	2026	2027	2028	2029	2030	2031		Total
Benefits	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2	$67.2		$1,143.1
Present Value	$27.9	$26.1	$24.4	$22.8	$21.3	$19.9	$18.6	$17.4	$16.2		$500.8
Costs	$33.2	$30.4	$33.2	$30.4	$33.2	$30.4	$33.2	$30.4	$33.2		$710.8
Present Value	$13.8	$11.8	$12.0	$10.3	$10.5	$9.0	$9.2	$7.9	$8.0		$375.5

Note. Adapted from "Notice of proposed rulemaking (NPRM), Docket Number FAA- 2009- 0671. (Federal Register: November 5, 2010, Volume 75, Number 214, 68224-68245)."

Table 2

Total Benefits and Costs Per Year for Only One Part 121 Carrier (in millions of dollars)

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Benefits	$0.0	$0.0	$0.0	$.75	$.75	$.75	$.75	$.75	$.75	$.75	$.75
Present Value	$0.0	$0.0	$0.0	$.53	$.50	$.47	$.43	$.41	$.38	$.35	$.33
Costs	$.63	$.63	$.63	$.37	$.34	$.37	$.34	$.37	$.34	$.37	$.34
Present Value	$.55	$.51	$.48	$.26	$.23	$.23	$.20	$.20	$.17	$.18	$.15
Year	2023	2024	2025	2026	2027	2028	2029	2030	2031		Total
Benefits	$.75	$.75	$.75	$.75	$.75	$.75	$.75	$.75	$.75		$12.7
Present Value	$.31	$.29	$.27	$.25	$.24	$.22	$.21	$.19	$.18		$5.6
Costs	$.37	$.38	$.37	$.34	$.37	$.34	$.37	$.34	$.37		$7.9
Present Value	$.15	$.13	$.13	$.11	$.12	$.10	$.10	$.09	$.09		$4.2

Note. In Table 2, cost and benefit data from Table 1 has been divided by the total number of Part 121 carriers (n = 90) to understand the benefits and cost estimation evident in the NPRM for only one Part 121 carrier. Adapted from "Notice of proposed rulemaking (NPRM), Docket Number FAA- 2009- 0671. (Federal Register: November 5, 2010, Volume 75, Number 214, 68224-68245)."

Economic theory was the basis for a cost-benefit evaluation performed by Chryssochoidis, Karagiannaki, Pramatari, and Kehagia (2009) to evaluate the cost of electronic traceability systems, which support legal compliance, safety, and quality assurance, and risk prevention in the food industry, which can be compared to product traceability in the aviation industry. The gap in the literature related to SMS program costs, safety initiative costs, and operational costs of mishap events in the U.S. may be attributed to safety regulations (49 CFR § 830) and the lack of requirements for cost information. However, the literature provided insight to the collection of accident investigation costs for the management of US government aircraft (OMB, 1992b). In addition, the difficulty in quantifying safety initiatives may be attributed to aviation industry not collecting financial data with the intention to conduct cost-benefit or trend analysis (Rosenkrans, 2012; Wang et al., 2013).

Project costs. Some researchers (Drewery-Brown, 2010; Gillard, 2009) have emphasized the importance of obtaining program cost prior to business initiatives. The focus of current literature has been on human performance deficiencies within organizations with little regard to the financial impact of safety initiatives. Aviation safety improvements typically do not have financially definable returns on investment (Hackworth et al., 2007), even though, the net worth of an airline may decrease by as much as 25% after an accident (Lercel et al., 2011). In the IT field, Irani (2010) examined four phases of the life cycle process: (a) *ex-ante* evaluation, (b) metrics, (c) command and control, and (4) *ex-post* evaluation, emphasizing that program evaluation needs to be viewed as a process that runs through the life cycle of a project rather than as a hurdle that needs to be cleared to ensure financial approval. Irani (2010) explained that investment evaluation needs to be viewed in parallel to project management activities to assist decision makers regarding to invest or not.

To date, there remains a gap in the literature related to the economics of aviation safety management (Ginieis, Rebull, & Planas, 2012; Wang et al., 2013), even though the global aviation authorities advocated SMS programs as early as the late 1990s (Ropp, 2008) and other programs such as the Aviation Safety Action Program (ASAP) and Flight Operational Quality Assurance (FOQA) early as 1994 (FAA, 2011b). Many U.S. operators have chosen to not participate in FOQA and participation is very low among small operators (Lowe et al., 2012). While the FAA authorities advocate that leaders of aviation organizations implement SMS programs (FAA, 2010a, 2010b), the lack of cost data and regulatory requirements may be due to certain legislative proposals requiring government agencies to provide cost-benefit analysis to examine the position of economic burdens to organizations (U.S. Office of Management and Budget, 1992). Managers may be reluctant to implement such programs because of the lack of empirical studies on program cost, quality cost, cost-benefit analysis, or ROI to support a business case (Markos & Sridevi, 2010; Tari, 2011, Wong & Yeh, 2007). The economical impacts related to workplace safety can be traced to Heinrich's work in the 1920s (Cagno, Mitchell, Masi, & Jacinto, 2013). In the context of SMS programs, the business case for quality and safety was typically supported in the literature by arguing social responsibilities, nonetheless one would question the emphasis related to accident investigative processes within the research and academia domains (accident case studies), which has suggested due diligence was not performed before the unsafe practice. Many SMS activities are influenced by various biases (Reiman & Rollenhagen, 2011), and single event investigations lack statistical relevance (Stoop & Dekker, 2012).

Data related to nonconforming products are typically examined to implement corrective actions and understand root causes. *Lean manufacturing*, or *lean production* (also known as *lean*), is a practice typically used in production that considers expenditures for nonconforming products wasteful (León & Farris, 2011; Main et al., 2008). Lean manufacturing is management philosophy derived from the Toyota Production System influenced by quality leaders such as Juran and Deming in the 1950s (Chenhall, 2008). The goal of *lean* manufacturing operations is to minimize waste and increase speed, whereas in product development processes, lean is used to maximize product value and quality, reduce waste, and increase development speed; however, the lean philosophy for production development has yet to be reached (León & Farris, 2011).

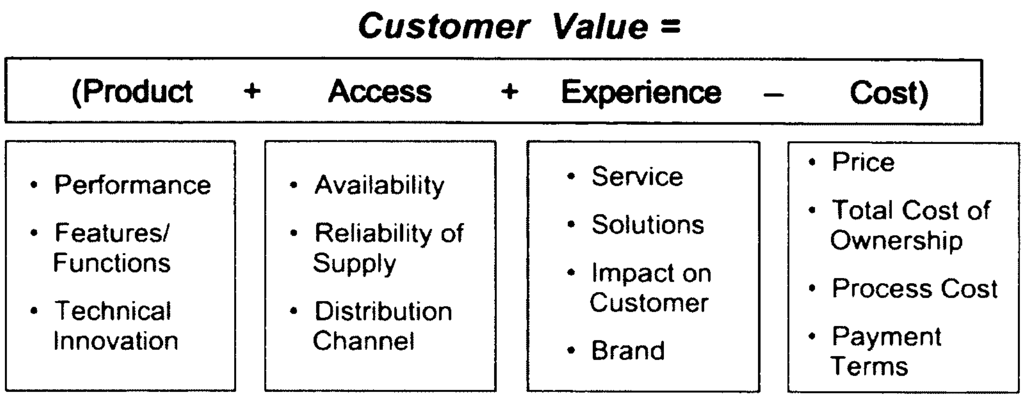
Cost analysis methodologies. Veltri and Ramsay (2009) explained that organizational leaders must understand cost burdens associated with new processes; however, little has been done to create economic analysis models to link business outcomes with safety issues. Studies related to cost analysis were reviewed to understand why projects typically overrun cost budgets and how to address the research questions. Traditional costing methods also make it difficult for safety managers to make a business case for safety (Rosenkrans, 2012). An organization's safety culture and workplace environment is one factor used to negotiate insurance premiums, although some researchers feel it has not been possible to quantify safety initiatives (Brahmasrene & Smith, 2009; Flouris, Hayes, Pukthuanthong-Le, Thiengtham, & Walker, 2009). The cost of investments in safety interventions when an accident event does not occur and the consequences if it did occur are trade-offs commonly simplified in economic models with a common unit, money (Abrahamsen & Asche, 2011).

Cost importance to an organization was emphasized by Briciu and Capusneanu (2010) in the context of how organizations use various tools for monitoring and measuring project performance such as dashboards and balanced scorecards. Baik (2011) explored the application of portfolio theory and proposed a framework that could be applied to projects. Michell and Braithwaite (2009) researched cost analysis methods to aid decision-makers who seek to mitigate future costs and assess the value of proposed safety initiatives in the context of aircraft accidents. The costs of accidents and incidents in Australia included productivity losses, property damage, loss of life, insurance administration, accident investigation, medical costs, workplace costs, emergency services, rehabilitation or long-term care, and legal costs (Australian Government Bureau of Transport and Regional Economics, 2006). The BLS (2012a, 2012b) provided data related to occupational employment and wage estimates for the aviation industry that could assist in project cost estimation and the development of decision-making models.

Earned value based methods have been used to forecast total project duration using Monte-Carlo simulations (Vanhoucke, 2012; Vanhoucke & Vandervoorde, 2007). Monte-Carlo simulations, or continuous event tree strategies, are typically used in project and risk management (Hubbard, 2009). Although many business initiatives related to risk management and project success criteria were evident in the literature (Abrahamsen & Asche, 2010; Artto, et al. 2009; Bryde, 2008), time standards for project duration, in the context of labor resources, were not evident, other than Mochal (2006) who reported productive labor hours per day were significant when estimating project duration.

Return on investment. Return on investment is a powerful tool for decision making in business (Andru & Botchkarev, 2011). Andru and Botchkarev postulated that ROI evaluation metrics must be transparent and accompanied with detailed descriptions and assumptions. The Australian government provided important information on how costs are calculated for ROI and aviation accidents (Lercel et al., 2011). Lercel et al. performed macro and micro levels analyses for a safety investment model to show the investment benefit of SMS. Additional guidance on return-on-investment for safety initiatives was provided by Johnson (2010) who explained the industry must pay increasing attention to financial and safety ROI that was ranked one of the top eight safety concerns in maintenance. According to Friend (2011), management typically expects a 10% ROI; however, literature related to SMS implementation cost was lacking. Making ROI calculations transparent for decision makers, as suggested by some researchers and practitioners (Al-Raisi & Al-Khouri, 2010; Andru & Botchkarev, 2011; Phillips et al., 2012), would be difficult without this knowledge.

Kothari and Lackner (2006) explained the value that customers place on various attributes of a companies' service or product they offer should be quantified in real dollars and cents. Kothari and Lackner postulated that there are four elements of customer value of products and services: (a) product, (b) access, (c) experience, and (d) cost (see Figure 3) and without this understanding companies fail to convey the real value of their offerings to the customers. Few statistics were available related to implementation cost or operational cost savings of SMS programs in the aviation industry; however, many of the airlines whose representatives had implemented Maintenance Error Decision Aid (MEDA) processes reported several organizational benefits (Allen, Rankin, & Sargent, 1999). The MEDA concepts are structured processes developed by representatives of the Boeing Company, a major aircraft manufacturer, to investigate events traced to the performance of maintenance personnel (Liang et al., 2010).



Note: The enterprise delivers value to customers across each of the dimensions of the relationship

Figure 3. Elements of customer value. Reprinted from "A value based approach to management," by A. Kothari and J. Lackner, 2006, *Journal of Business and Industrial Marketing, 21*, p. 245. doi:10.1108/08858620610672614. Copyright 2006 by EmeraldInsight. Reprinted with permission (see Appendix A).

Risk Management

Risk management is commonly used in various industries to support decision-making (Abrahamsen & Aven, 2012; Aven, 2013). Risk management is often perceived as the practices to mitigate the effects of accidents, supply chain disruptions, price volatilities, etc. (Andersen, 2008). Literature related to risk management techniques was considerable (Abrahamsen, 2011; Aven, 2010; 2011a, 2011b, 2011c, 2011d, 2012a, 2012b; Aven & Steen, 2010; Aven & Zio, 2011; Cabon, Deharvengt, Grau, Maille, Berechet, & Mollard, 2012; Cox, 2008, 2011a, 2011b; Ersdal & Aven, 2008; Everett, 2011; Flange & Aven, 2009; Hall, 2010; Hopkins, 2011; Hubbard, 2009; Kongsvik, Almklov, & Fenstad, 2010; Leitch, 2010; Lin & Chang, 2008; Paté-Cornell, 2012; Purdy, 2010; Rogerson & Lambert, 2012). Most researchers noted that aviation safety statistics were extremely low, and a critical need existed to be more proactive in analyzing safety data (Arminen et al., 2010; Groen et al., 2010; Herrera et al., 2009; Kontogiannis & Malakis, 2009; Logan, 2008; Lu, Young, et al., 2011; Ma et al., 2011; Mokaya & Nyaga, 2009; Stoop & Dekker, 2012). Murphy and Conner (2012) postulated process safety incidents always have warning signs that can help control minor events, that if controlled, help reduce the probability of larger events such as *black swans*. Black swans and perfect storms were metaphors noted in the safety literature (Aven, 2009; Paté-Cornell, 2012) as catastrophic events that were not perceived through traditional risk analysis methods. For example, the BP explosion in the Gulf of Mexico and the tsunami event in Japan were rare and unpredictable events that lie outside regular expectations (Murphy & Conner, 2012). Black swans can be easily understood by layman as the outliners in risk management data typically dismissed by researchers and practitioners (Taleb, 2010, 2012).

Two noteworthy publications, Aven (2011c) and Leitch (2010) provided reviews of ISO 31000:2009, *Risk management- principles and guidelines*, because the recently released standard have significant impact on the risk management field and has been the subject of debate. Hubbard (2010) provided a definition of risk and uncertainly, as well as examples of the measurement of risk and uncertainly. According to Hubbard (2010), risk is defined as "the probability and magnitude of a loss, disaster, or other desirable event" (p. 8) and further explained risk is "a state of uncertainty where some of the possibilities involve a loss, injury, catastrophe, or other undesirable outcome" (p. 80). In contrast, Hubbard explained uncertainty is "the lack of complete certainty- that is, the existence of more than one possibility" (p. 80). In the context of risk management, Berry, Coad, Harris, Otley, & Stringer (2009) suggested additional research is needed which attends to the relationship of theory and control practices.

One noteworthy book related to accident prevention and risk management was Sidney Dekker's *Drift into failure: From hunting broken components to understanding complex systems* (2011) where complexity theory and systems thinking were explored to understand how organizations slowly drift into failure. Dekker explained how small incremental decisions over several years produce breakdowns in complex systems. To emphasize his point, he discussed a well-known accident that occurred on January 31, 2000 involving Alaska Airlines Flight 261 in which 88 passengers and crew perished and the aircraft was destroyed. Literature related to flight 261 was considerable (Coury, Ellingstad, & Kolley, 2010; Dekker, 2011; Madden, 2011; Okstad, Jersin, & Tinmannsvik, 2012; Mawhinney, 2009; Wooten & James, 2008) since the probable cause was reported as a loss of control after the failure of the horizontal stabilizer jackscrew due to insufficient maintenance and other contributing factors related to risk management. Dekker (2011) discussed the Alaska Airlines accident in relation to an organizations drift into failure. Dekker explained how drift occurs over a considerable timeframe and explained the Alaska Airlines accident was "normal people doing normal work around seemingly normal, simple, stable technology" (p. 44), yet their actions resulted in a fatal accident. Dekker postulated Cartesian and Newtonian ideas are faithfully reproduced in safety related literature and practices that limit how we think about failure.

Safety Culture

Safety culture has become the focus of attention in many industries as an approach to accident prevention and risk mitigation within safety management programs (Antonsen, 2009; Guldenmund, 2010; Ropp, 2008). The literature on safety culture was considerable (Allen, Chiarella, & Homer, 2010; Fernández-Muñiz, Montes-Peón, & Vázquez-Ordás, 2009; Goh, Brown, & Spickett, 2010; Hale, Guldenmund, & van Loenhout, 2010; Haukelid, 2008; Hendershot, 2011; Kirwan, 2011; LaPoint, 2012; McCune, Lewis, & Arendt, 2011; Marx, 2009; Mengolini & Debarberis, 2012; Mohaghegh & Mosleh, 2009b; Rollenhagen, 2011; Santos, Barros, Mendes, & Lopes, 2013; Sharpanskykh & Stroeve, 2011). Safety culture has been broadly recognized by many disciplines as the backbone of safety operations (Shirali, Mohammadfam, Motamedzade, Ebrahimipour, & Moghimbeigi, 2012; Stroeve, Sharpansky, & Kirwan, 2011; Sujan, 2012). Weak safety culture has often been identified as a contributing cause to mishaps (Johnson, C. W. et al., 2009; Martínez-Córcoles, Gracia, Tomás, & Peiró, 2011; Mokaya & Nyaga, 2009). In contrast, Rollenhagen (2010) argued that safety culture and safety climate concepts might legitimate non-safe norms and behaviors within organizations. Marx (2009) postulated there are two inputs impacting our ability in which we have control to avoid mishaps: (a) the system design and (b) the behavior choices we make within the systems.

The need to measure safety culture and safety climate within organizations was emphasized in the literature in various industries such as aviation (Lu, Young, et al., 2011; Mearns et al., 2013; O'Conner, Dea, & Kennedy, 2011), healthcare (Allen, Chiarella, & Homer, 2010: Sujan, 2012), military (Fogarty & Buikstra, 2008), nuclear

(Martínez-Córcoles et al., 2011; Mengolini & Debarberis, 2012), and others (Antonsen, 2009; Colley & Neal, 2012; Keren et al., 2009; Remawi, Bates, & Dix, 2010). In the construction industry, Conchie, Moon, and Duncan (2013) used focus group data to examine supervisors' roles to engage employee participation in safety management. Conchie et al. found barriers to supervisor's safety leadership behaviors were role overload and production pressures. In a noteworthy study (Colley & Neal, 2012), safety schemas of different employees from safety climate theory perspective found upper management, supervisors, and workers concerns with safety differed. Semi-structured interviews were conducted with a total of 25 employees of an Australian rail company (six upper managers, seven supervisors, and 12 operational employees). The interview transcripts were transferred to a Microsoft Excel spreadsheet for pre-processing before using Leximancer v3.1, a software application designed to analyze qualitative data. A significant finding of Colley and Neal's study found upper management were concerned with people and culture; supervisors were concerned with management practices, safety communication, and corporate values; and workers were concerned with procedures and safety training. Colley and Neal concluded the differences between upper management, supervisors, and workers concerns with safety represent a barrier to communication within organizations.

Antonsen (2009) postulated issues of risk and safety are actually issues of power and suggested that safety culture research should include perspectives of power and conflict. Normal accident theory (Perrow, 1999) is well known by researchers and practitioners of the safety discipline and was evident in much of the safety literature (Aase, Wiig, & Hoyland, 2009; Dekker, 2009a, 2010, 2011; Dekker, Cillers, & Hofmeyr, 2011; Dov, 2008; Downer, 2011; Holtman, 2011; Hovden et al., 2010; Hovden, Størseth, & Tinmannsvik, 2011; Le Coze, 2008; Mohaghegh & Mosleh, 2009b; Rollenhagen, 2011) and Perrow postulated "we miss a great deal when we substitute power with culture" (p. 380). The researcher further suggested a need to question organizational power structures that impose or accept risks in systems and to find ways to make efficiency align with safety and culture (Perrow, 1999).

Change Management

Effective leadership is a crucial concept in managing change (Nadler & Tushman, 1990). Both the FAA and ICAO SMS framework documents (DOT, 2010; ICAO, 2009) describe change management processes but in slightly different language (Yantiss, 2011). In a study (Hsu et al., 2010) of critical success factors of an SMS program, change management was ranked 25 out of 25 in importance from 28 safety experts. Hsu et al. defined change management, in the context of quality assurance, as "a process to evaluate the effectiveness of corrective actions" (p. 226); however, change management, in the context of organizational management, was not identified as a critical success factor in this study. In contrast, Lofquist (2010) studied the effects of change on perceptions of safety and found negative individual perceptions at a Norwegian air service provider during the interactive phase of an SMS model. Lofquist explained the interactive phase as the most critical phase of SMS programs with the greatest the potential contribution to improving safety outcomes. The interactive phase is where deviations from expected system performance are directly observable and first detected. Flouris and Kucukyilmaz (2009) argued change management is necessary to successfully transform existing systems into SMS compliant systems.

The success of SMS programs has been suggested by some to depend on top management commitment (Chen & Chen, 2012; Cox & Flouris, 2011; Čokorilo et al., 2011). Further, Chen and Chen postulated employee participation is the key to successful SMS implementation. However, managers must understand that employees can impede or enhance the progress of any initiative in an organization (Garcia-Sabater, Marin-Garcia, & Perello-Marin, 2010; Mehralizadeh & Safaeemoghaddam, 2010). According to Kets de Vries and Balazs (1997), researchers found that middle managers will withdrawal during change processes until they understand it themselves. Saksvik et al. (2007) stated that middle managers set the tone for the organization and define and influence organizational culture. The impact of change on individuals who accomplish organizational tasks without being prepared remain largely unknown (Scharitzer & Korunka, 2000).

Zikmund (2003) explained an organization's employees are most likely aware of problems within the company and are eager to provide input. Employees are typically included in the brainstorming processes to help manage negative consequences of change since the choices made by management may affect them personally, and they may provide insight for better services before they are passed on to customers (Deming, 1986; Juran, 1995). Some researchers (Kongsvik et al., 2010; Roed-Larsen & Stoop, 2012) advocate process owners, or stakeholders, should be given the opportunity to develop measures to improve the system, which help lead to effective actions and correct current policies, which follows Deming's (1986) teachings.

One approach suggested by experts to help facilitate (or adapt to) change in an organization is the implementation of productivity improvement programs (a.k.a.

suggestion programs) to encourage employees to identify problems and share ideas for organizational improvement (Deming, 1986). Boeing, a leading aircraft manufacturing company, reported that many companies who adapted their model of an improvement program helped to save costs and reduce mechanical delays by 16% (Allen, Rankin, & Sargent, 1999). However, risks identified by employees via suggestion boxes, a method considered by some as a form of improvement programs, are reviewed by people who have no real authority to make change (Linstone & Turoff, 2011). Improvement programs depend on employee willingness to speak up and identify organizational problems (Flouris & Kucukyilmaz, 2009; Holtman, 2011; Verhezen, 2010). According to Morrison and Milliken (2003) in many cases employees choose to remain silent out of fear of being punished. Researchers refer to this as employee silence or organizational silence (Tangirala & Ramanujam, 2008; Verhezen, 2010). According to Verhezen, overcoming silence require management to move their organization's culture toward integrity and trust.

The literature review also included an examination of theories on why employees may not report known problems discovered during mishap investigations (e.g. employee silence, trust, ethics, and motivation). Problem solving processes and brainstorming sessions may not be effective if individual and organizational defensive routines impede members of an organization understood as employee silence due to lack of trust (Zikmund, 2003). Existing management strategies previously neglected must be changed to encourage members to engage in the problem solving process and change the organizational culture (Rahim, 2002). Morrison and Milliken (2003) explained employee silence may be caused by fear (labeled or viewed negatively, damaged relationships, not being listened to, and retaliation or punishment), the desire to avoid unwelcomed ideas, or social pressures within a group. Trust, or the lack of, will impede brainstorming since employees were less likely to participate if they previously reported company issues but management did not take corrective action (Covey & Merrill, 2008; Zikmund, 2003). Researchers and practitioners have begun to examine the relationship between trust and safety behavior (Conchie, Donald, & Taylor, 2006). A consulting firm may be able to obtain the trust of employees if it appears management is attempting to do the right thing and working toward making appropriate changes (Covey & Merrill, 2008; Zikmund, 2003).

Decision Support Systems

The definition of a decision support system in the literature was dependent on the context within various disciplines with much focus on computerized information systems (Buryak et al., 2008; Dahl & Derigs, 2011; Louvieris, Gregoriades, & Garn, 2010). As restated from Chapter 1, for the purpose of this study, a decision support system is defined as a management tool developed by experienced persons and approved by policy makers to be used by others to assist in decision-making activities to increase efficiency (Buryak et al., 2008). Decision support system models included the documents, knowledge, and data available to assist decision makers solve problems, complete tasks, and make decisions aimed at increasing the efficiency of activities (Allen & Abate, 1999; Baldwin, Allen, & Ridgway, 2010; Khataise, Bulgak & Segovia, 2011).

Emerging themes in management control where reviewed by Berry et al. (2009) and structured around decision making and various management control models, both in practice and in theory, to provide ways of thinking about costs, value, and performance.

Decision support systems, particularly computer based, have been suggested to improve decision-making of less experienced personnel (Perry, Wiggins, Childs, & Fogarty, 2012; Pettersen & Aase, 2008). Considerable attention has been given to regulatory authorities' safety oversight in regards to decision support systems of surveillance activities and risk analysis processes (Allen & Abate, 1999).

Decision support systems for SMS cost estimation were not evident in the literature, although airline mishaps and decision support systems for cost estimation have been investigated in several ways. Madsen (2013) examined the profit-safety relationship from the perspective of behavior theory of the firm to explain the profit-safety link and how organizational leaders make decisions. Wang et al. (2013) examined the financial aspect of safety investments and financial health of airlines in relation to accident propensity. Wang et al. collected accident data from the NTSB safety database and operating and financial data from the Bureau of Transportation Statistics. Quantitative measurement and comparison of safety-related problems have been conducted (Cocklin, 2010; Fogarty & Buikstra, 2008; Kenett & Salini, 2008; Monaghan, 2011). For example, Monaghan (2011) examined the aircraft safety rates of maintenance outsourcing and found there was no statistical significant correlation between aircraft maintenance outsourcing and accidents and incidents; however, 95.8% of the pilot deviations were unexplained.

From a business perspective, mishaps create high operational costs for organizations (Carey & Stefos, 2011; Johnson, W. B, 2009; Stolzer et al., 2010); therefore, preventing or reducing mishaps leads to reduced operational costs (Lin & Chang, 2008). Mohaghegh and Mosleh (2009a) explained that the direct costs of accidents effects the financial performance of an organization quicker than its safety culture, and Mohaghegh-

Ahmadabadi (2007) introduced an organizational risk framework, named Socio-Technical Risk Analysis (SoTeRia), which considers the theoretical relation between organization safety culture, climate, and practices. Additional quantitative research could test a theory that an organization's surveillance data may be related to the organization's safety data applying control theory, intervention theory and theory of quality management.

Decision support system tools. Various corporate performance measures and decision support tools were evident in the literature (Ayvaz & Pehlivanli, 2011; Barclay, 2008; Briciu & Capusneanu, 2010; Hagos, 2010; Modell, 2009). Business functions are typically performed with some form of IT based system (Callaway et al., 2009). According to Callaway et al., the use IT capabilities may relate to efficiencies in terms of operations and costs. Many aviation organizations use some form of computer-based system to collect data related to business initiatives and safety data (Nazeri, 2003).

In relation to the example provided in Chapter 1 for the definition of a decision support system, standard operating procedures and minimum equipment lists (MEL) are typically provided as a decision support tools for flight and ground crews to evaluate the airworthiness of an aircraft (Atak & Kingma, 2011; Øien, Utne, Tinmannsvik, & Massaiu, 2011; Papakostas et al., 2010; Johnson et al., 2009). Standard operating procedures and MELs are tools the aviation industry use to increase efficiency, manage safety, and in effect, control costs (Atak & Kingma, 2011; Herrera et al., 2009; Papakostas et al., 2010) and are similar to management controls used in other industries (Lu & Tseng, 2012; Mitchell, Friswell, & Mooren, 2012). Standard operating procedures are in essence the formal agreements between the governing regulatory authorities and organizations, in addition to the formal agreements between management and employees, on how business is conducted in a safe and efficient manner consistent with industry best practices and regulatory requirements (Keren et al., 2009). However, problems arise when pressures to produce a product or deliver a service in degraded modes are ignored or lead to the use of waivers for the procedures designed to control safety and efficiency (Johnson, C. et al., 2009). For example, in the context of waivers, the controversy between Southwest Airlines and the FAA representatives after an audit discovered 46 Boeing 737s were allowed to stay in service after Southwest failed to inspect the aircraft (Madsen, 2013; Thorn, 2008). Congress became involved after implications of systemic failure with FAA safety oversight, which led to a $10.2 million fine for Southwest, the largest fine in U.S. aviation history (Shannon, 2008). This breach of due diligence within the industry raised questions about the link of profitability and aviation safety (Madsen, 2013).

In a study (Marais & Robichaud, 2012) of FAA records from 1999 to 2008 there were 7,478 fines and legal actions taken against aviation entities totaling US$8.6 million. Research studies (Pettersen & Aase, 2008; Li et al., 2008) support arguments that slack in some areas of management result in poor supervisory oversight, willful violations of policies, and the effectiveness of work practices. Many unsafe acts have been linked to noncompliance with standard operating procedures and violations are troublesome in aviation (English & Branaghan, 2012; Hadjimichael, 2009; Ji, You, Lan, & Yang, 2011; Johnson, C. W. et al., 2009; Matthews, 2010) as well as other industries (Gordon, 2008; Grote, 2012; Keren et al., 2009).

Summary

In a study that examined the changing interests in air transportation between 1997 and 2009 (Ginieis, Rebull, & Planas, 2012), the majority of the 1059 research studies were identified with management themes (29.7%), whilst themes identified with costs (4.6%) and safety (2.6%) accounted for a total of 7.2% of the studies. A major peer-reviewed journal published by the FAA academy, the Journal of Applied Aviation Studies, was not included in Ginieis et al. study, although only literature categorized as transportation was analyzed. Although locating scholarly literature specific to the aviation industry and the business benefits of safety management was a challenge, noteworthy SMS literature was available indicating analytical and theoretical frameworks for SMS implementation (Flouris & Kucukyilmaz, 2009; Hsu et al., 2010; Lofquist, 2010). Decision-making criteria were evaluated in the context of context of quality management theory (Mauléon, & Bergman, 2009; Redmond, et al., 2008), safety (Aven & Flage, 2009; Bruce, 2011), risk (Aven, 2010, 2011c, 2011d, 2012a, 2012b; Aven & Zio, 2011; Buryak, Insarov, & Kalinina, 2008; Ersdal & Aven, 2008; Hopkins, 2011), and cost (ASA, 2011; Huang, Leaman, Courtney, DeArmond, Chen, & Blair, 2009). The review provided insights into research on error management and how safety data have traditionally been reported, collected, and stored (Australian Government Bureau of Transport and Regional Economics, 2006; Flouris & Kucukyilmaz, 2009; Stoop & Dekker, 2012).

Although SMS guidance documents (DOT, 2010; ICAO 2009, 2012) suggested SMS frameworks follow the principles of QMS, there was little emphasis in the literature of continuous improvement efforts related to risk management already imbedded in quality standards. However, barriers that hinder the business benefits of QMS programs has been investigated in other industries (Kumar & Balakrishnan, 2011; Levine & Toffel, 2010; McGuire & Dilts, 2008). In addition, several organizations have invested in SMS program implementation with no quantifiable ROI (Komarniski, 2001), while others (Adebiyi et al., 2007; Wang et al., 2013) concluded that the financial implications of safety programs have not been addressed.

Decision-making involving risk in the context of accident loss, disaster management, and management strategies to improve business outcomes was evident in the literature (Aven, 2010; Rosness, 2009; Tarn, Wen, & Shih, 2008; Turnbeaugh, 2010; Van de Walle & Turoff, 2008). Strategies for making a business case for safety programs were also evident in the literature (Jallon et al., 2011; Lercel et al., 2011). In the context of safety and health programs, Huang et al. (2009) found executives perceived the benefits of safety programs were predominantly financial in nature.

Deficiencies with how data are reported, collected, and stored in the aviation industry were evident in the literature (Shappell & Wiegmann, 2000; Nazeri, Barbara et al., 2008; Smith et al., 2010), yet remain a concern as regulatory authorities are focusing on a risk-based approach to safety oversight (Sawyer, Berry, & Blanding, 2011). The gap in the literature related to safety initiative costs and operational costs of mishap events in the U.S. may be attributed to the lack of requirements for cost information within the safety regulations (49 CFR § 830; Hansen et al., 2006). The difficulty in quantifying safety initiatives may be due in part to aviation authorities not collecting financial data with the intention to conduct cost-benefit or trend analysis (Rosenkrans, 2012).

Chapter 3: Research Method

The purpose of the qualitative study was to identify key factors in a decision support system framework for SMS program cost estimation. The qualitative study included the development of a decision support system framework for SMS program cost estimation. The study sought to determine key SMS program cost parameters to provide decision makers with a framework for SMS program strategies. The research questions that guided the study were as follows:

Q1. What do experts in the aviation industry perceive are the key factors in the development of a decision support system for SMS cost estimation?

Q2. How can SMS project cost estimates be modeled using existing information sources in the aviation business environment?

In Chapter 3, the methodology of the study is presented then restating the research problem, the purpose of the study and the research questions. Chapter 3 includes the research design and the following sections: research method and design, participants, materials/instruments, data collection, processing and analysis, methodological assumptions, limitations, delimitations, and ethical assurances followed by a summary highlighting the research design.

Research Method and Design

The research method chosen for the study was a qualitative approach using a modified Delphi technique (Bolger & Wright, 2011; Grisham, 2009; Hallowell & Gambatese, 2010). The problem addressed in this study was SMS programs have not always been implemented in the aviation industry, as actual program costs could not be determined comprehensively and definitively. Although the ICAO SMS program model

(ICAO, 2009) identified key factors such as task time standards, it did not include other key factors typically needed for program management and transparency of safety and financial risks (Lu, Young, et al., 2011; Mitchell & Braithwaite, 2008). Further research is needed to identify key factors of SMS models in order to link costs to business advantage (Cox & Flouris, 2011; Rosenkrans, 2012).

The purpose of the qualitative study was to identify key factors in the use of a decision support system framework for SMS program cost estimation. Specifically, it explored how SMS cost estimates may be modeled using existing information sources to provide decision makers with a framework for SMS program strategies (Lu, Young, et al., 2011). The use of measuring instruments and structured interviews were strongly considered in the research design but were rejected as not the best fit for this study after review of literature related to project success (Malach-Pines, Dvir, & Sadeh, 2009; Dvir & Shenhar, 2011); preferences of different personality types (Baba et al., 2009; Meyers & Meyers, 1995), problem-solving and decision-making (Huitt, 1992; Liang & Zhang, 2010; Perry et al., 2012). Individuals' preferences and approaches to problem solving and decision-making influenced the study design. Meyers and Meyers (1995) explained orderly reasons for personality differences (as measured by the Myers-Briggs Personality Indicator [MBPI] test) and extended the knowledge of personality preferences in terms of Jungian psychological type theory to understand why people with difference personalities act the way they do, specifically, learning styles, preferences, and personality limitations.

A modified Delphi method allowed for criteria selection such as key factors in a decision support system for SMS program cost estimation, which was best suited for this particular qualitative research as it prioritizes issues for managerial decision-making and facilitates clarification of issues when accurate information is unavailable such as in the need for a decision support system framework for SMS program cost estimation (Barclay, 2008; Linstone & Turoff, 1975, 2011; Turoff, 1970). The modified Delphi model differs from the classic Delphi in that questionnaires are sent via e-mail instead of the mail system (Delbecq, Van de Ven, & Gustafson, 1975). Quantitative methods involve the collection and analysis of numeric data presented for quantitative analyses (Teddlie & Tashakkori, 2009); thus, a qualitative approach was more suited for the study as the method involves collecting open-ended data with the intent to develop themes (Teddlie & Tashakkori, 2009). Qualitative methods are emergent and flexible using purposefully selected cases or people with lived human experience (Greene, 2007). A quantitative approach would not be suited for the study due to the type of data to be collected and the constructs to be investigated. Thus, the type of data that was collected in the study directly and appropriately influenced the design of the study (Goluchowicz & Blind, 2011; Teddlie & Tashakkori, 2009; Zikmund, 2003).

A system can be viewed through several theoretical lenses to offer decision makers choices for project decisions and investments (Linstone, 1984; Linstone & Turoff, 2011). For example, although SMS guidance (DOT, 2010) defined a SMS as a "formal, top-down business-like approach to managing safety risk" (p. 8) the critical lenses of financial management from the business perspective were not emphasized. The design of the study was influenced by several researchers (Conboy, 2010; Deming, 1986; Patton, 2002; Zikmund, 2003), who emphasized the appropriateness of theoretical lenses and the use of person's knowledge in business that can provide different perspectives.

Strategies for possibly applying grounded theory, the discovery of theory from data (Glaser & Strauss, 1967), for the study were reviewed with reference to the literature (Artto et al., 2009; Patton, 2002; Steinert, 2009; Teperi & Leppänen, 2011). In addition, literature related to other research approaches such as ethnography (Arminen et al., 2010; Atak & Kingma, 2011; Chenhall, 2008; Fanjoy, Harriman, & Demik, 2010; Holloway & Todres, 2010; Høyland, 2012) and phenomenology (Downing, Chipulu, Ojiako, & Kaparis, 2011; Mehralizadeh & Safaeemoghaddam, 2010; Todres & Holloway, 2011) were reviewed to understand the best design for the study. Ethnography research is a means to understand lived experiences (Fanjoy et al., 2010), which in the context of the study, could be understood as the culture of project managers but was not the best fit for this study. According to Holloway and Todres (2010), ethnography focuses on culture or social group routine activities and customs in culture, which is not the focus of the study. The research paradigm for this study is qualitative using a constructive lens of Deming (1986), Anderson et al. (1994), and others such as Zikmund (2003) to identify key factors to be found in a decision support system framework for SMS program cost estimation.

Stakeholder involvement is crucial when evaluating organizations (Geist, 2010) and essential to rigorous practice-based inquiry (Hasson & Keeney, 2011). The Delphi technique involves soliciting expert opinion when accurate information is unavailable (Hasson & Keeney, 2011; Linstone & Turoff, 1975, 2011) and aims to "determine, predict and explore group attitudes, needs and priorities" (Hasson & Keeney, 2011, p. 1696). The Delphi technique is characterized by informed experts drawing on two critical sources of data: past experience and in-depth knowledge in order to provide information regarding a complex problem (Adelson & Aroni, 1975; Cavalli-Sforza &

Ortolano, 1984). Strategies to ensure rigor of the study, as suggested by several authors (Geist, 2010; Goluchowicz & Blind, 2011; Hasson & Keeney, 2010, 2011; Krefting, 1991; Teddie & Tashakkori, 2009; Wright & Rowe, 2011; Zikmund, 2003), were adopted into the design to establish integrity and trustworthiness: credibility, dependability, confirmability, and transferability. The study design consisted of a preliminary assessment, study announcement and participant solicitation, followed by three Delphi rounds.

Preliminary assessment. A preliminary assessment involved exploring the subject under discussion and was used to evaluate the Delphi questions for Round 1, identify Delphi panelist selection criteria, and determine the validity of the initial drivers provided in the ICAO SMS project model as suggested by the literature (Bolger, Stranieri, Wright, & Yearwood, 2011; Linstone & Turoff, 1975). The preliminary assessment team was asked via e-mail (see Appendix B) to perform a preliminary assessment following guidance material (see Appendix C). The preliminary assessment guidance material included information and instructions that provided background information, study procedure, participation confidentiality, risks and benefits of participation in the study, first round questionnaire (see Appendix D), participant qualifications, instructions for preliminary assessment, and contact information.

The preliminary assessment was conducted by aviation industry professionals and stakeholders familiar with SMS programs and program management, but not necessarily experts in project management and cost analysis for project planning. Aviation personnel employed with the FAA or ICAO were not affiliated with the preliminary assessment to ensure that biases were not inadvertently included in the first round of questions.

Participant years of experience in the aviation industry ranged from 14 years to 40 years, and experience in project management and cost analysis ranged from 5 years to 24 years. Three of the preliminary assessment participants were not part of the final study sample.

Assessment of Round 1 questions. Linstone and Turoff (1975) noted researchers must carefully write the initial questions in a Delphi study to focus on the desired objectives but not bias the responses. A preliminary assessment of the first round of questions was conducted to discover meaningful information and expectations prior to the Delphi rounds. The first round questionnaire is provided in Appendix D. All four preliminary team members discussed the first round questionnaire, but no changes were suggested for the survey instrument.

Assessment of Delphi panel selection criteria. The process for selecting experts is critical to the Delphi method and serves to provide validity to the study (Hallowell & Gambatese, 2010; Okoli & Pawlowski, 2004). The qualitative study design employed a modified Delphi technique to allow for a panel of aviation industry experts to contribute a critical knowledge base not found in the layperson to the study (Linstone & Turoff, 2011). The preliminary assessment included soliciting thoughts on panel selection criteria following procedures noted by Goluchowicz and Blind (2011) and Zikmund (2003). All preliminary assessment participants provided input for the Delphi panelist's expert criteria. One selection criterion was deleted based on the preliminary assessment results.

ICAO SMS project model. The preliminary assessment was conducted by aviation industry professionals and stakeholders to establish the validity of the initial drivers provided in the ICAO SMS project model (ICAO, 2009). The ICAO SMS project model provided data in the format of a task specific work scope that followed ABC principles. All four assessment team members provided discussions of the ICAO SMS project model. The preliminary assessment team identified three items decision makers would be interested in for SMS cost estimation modeling: (a) time commitments and costs, (b) schedules, and (c) resource commitments (i.e., funding sources, training, third party appraisals). The preliminary assessment team identified six additional topics for discussion: (a) training, (b) schedules, (c) expenditures for IT, (d) types of risks associated with organizational costs, (e) expenditures for administrative (record keeping), and (f) necessity to understand data security. Hazard identification and risk assessment elements of SMS may be the most important novel elements to be added to most traditional quality assurance systems by participants; yet, they were not the only elements that would have measurable costs.

Study announcement and participant recruitment. Managers at several professional organizations (see Appendix E) were asked via e-mail correspondence to post a participant recruitment solicitation (see Appendix F) to their websites to solicit study participants. An e-mail (see Appendix G) was sent to each Delphi panelist prior to the first round of questions to explain the purpose of the study, the estimated time required by each expert to complete the study, briefed on the address of the website where the ICAO SMS program model could be viewed, and to answer questions panelists may have had related to the topic. Each panelist was asked to provide e-mail addresses to expedite communications. An informed consent letter (see Appendix H) was provided via e-mail to each Delphi panelist with an assurance that confidentiality during the study would be maintained. Panelist' anonymity was maintained during the study to reduce issues such as undue persuasion (Linstone & Turoff, 1975). Panelists were required to acknowledge accepting panel membership via e-mail correspondence. Panelists were also given the option to remain anonymous or receive recognition for participation after the study as suggested by several researchers to improve panelist recruitment and retention over Delphi rounds (Bolger & Wright, 2011; Rowe & Wright, 2011).

Delphi rounds. Opinions from a panel of experts were queried in a series of three rounds by means of questionnaires. At the end of each round, feedback was provided to members of the Delphi panel so that they may modify their previous answers. The feedback process in Delphi studies is vital since it is the only communication between panelists (Murphy, Black, Lamping, McKee, Sanderson, Askham, & Mateau, 1998). Feedback is typical of Delphi studies and encourages participants to become more involved (Geist, 2010; Keeney, 2010). In many Delphi applications, the feedback procedures report statistical measures of panelist opinion (Bolger et al., 2011). Bolger et al. postulated that influences on opinion change such as dominance, confidence, and majority consensus should be removed from Delphi feedback. According to Norwack et al. (2011), feedback to panelists plays an important role and should include synthesized arguments and ideas. Consistent with the Delphi method, controlled feedback included a summary of the responses to allow panelists to reflect on the group perspective as suggested by the literature (Geist, 2010; Gnatzy, Warth, von der Gracht, & Darkow, 2011; Hallowell & Gambatese, 2010). The Delphi method reached stability in the responses among a number of experts without permitting social interaction. The procedures for each round are briefly discussed. Figure 4 illustrates a complete cycle of the Delphi approach for the study.

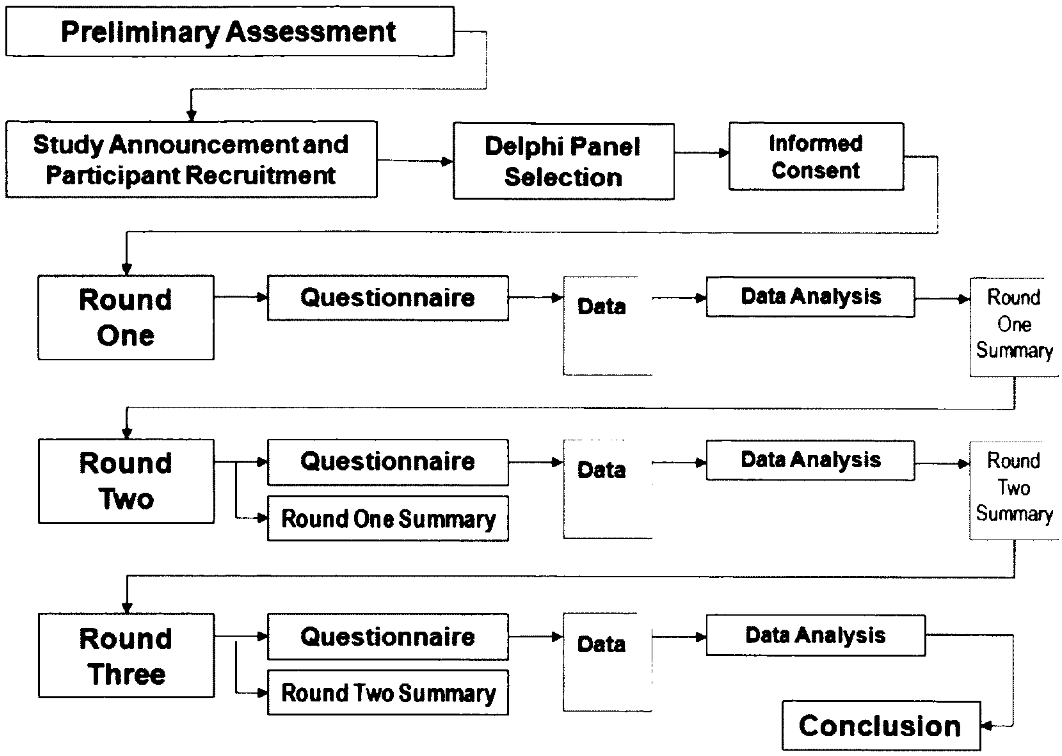


Figure 4. Delphi design. The complete cycle of the Delphi approach is illustrated. The study design consisted of a preliminary assessment, study announcement and participant solicitation, followed by three Delphi rounds. The figure was created by N. Duncan using Microsoft PowerPoint software.

Round 1 involved reaching an understanding of how the group viewed the issue. In Round 1, e-mail communication (see Appendix I) provided instructions and the Round 1 questionnaire (see Appendix D). Round 2 involved exploring the reasons for the differences discovered in Round 1. Round 3 included initial analysis that was returned to the panelists for final response and consideration. Qualitative analysis was performed after data was collected and transcribed to a summary sheet for the panelists. The process was repeated each round until stability of the research parameters was achieved.

Linstone and Turoff (2011) emphasized from their earlier work (1975) that the number of Delphi rounds depends on when stability of the responses is attained. The criterion for stopping the Delphi rounds is subjective (Holey, Feeley, Dixon, & Whittaker, 2007). Keeney (2010) postulated the researcher should establish a consensus level before data collection and noted the researcher defines what percentage agreement they are willing to accept. Differences between panelists opinion can provide value since differing positions can be used by decision makers. Discensus between panelists was considered valuable to this study because differing positions can be used to by decision makers as a decision tool (Turoff, 1970). Klenk and Hickey (2011) presented a variation of the Policy Delphi method integrating group knowledge and concept mapping of both consensus and dissent. Holey et al. (2007) postulated that consensus is the same as agreement and can be determined by confirming stability in the consistency of answers between successive rounds. Achieving stability of the responses was the focus of this study since differences in expert opinions may be of interest to decision makers. Panelist agreement was judged when 75% of the panelist responses were in agreement within at least one like response on the Likert-type scale. Stability was defined as the consistency of answers between successive rounds. In order for the Delphi method to provide value for this study, the focus of the third Delphi round was to achieve stability of responses as suggested by the literature (Chang & Yang, 2010; Duru et al., 2012; Linstone & Turoff, 2011).

Participants

The selection of participants and sample size affect most Delphi studies (Hung, Altschuld, & Lee, 2008) and the size of a Delphi panel may vary from three to hundreds of individuals (Grisham, 2009; Hallowell & Gambatese, 2010; Hung et al., 2008). The Delphi technique allowed for a purposive sample of experts and included the selection of a purposeful sample to identify a Delphi panel of four aviation management experts in project management and cost analysis for project planning. The sample size of four Delphi panelists was justified by the literature (Hallowell & Gambatese, 2010; Hung et al., 2008) and specific research studies (Shirazi, 2009) that addressed the appropriateness of sample size to capture the perceptions of expert opinion and address the research questions. Panel member qualification criteria were defined by a small group of experts in a preliminary assessment as having a distinct level of expertise to represent the aviation field.

Potential participants who responded to the study announcement and participation recruitment solicitation received an e-mail of informed consent and a request to complete a demographic questionnaire. The demographic data were used to validate inclusion to the Delphi panel. A Knowledge Resource Nomination Worksheet was created in Microsoft Excel became an administrative tool used to track responses to the participant solicitation (Delbecq et al., 1975; Keeney, 2010; Okoli & Pawlowski, 2004). An example of the Knowledge Resource Nomination Worksheet is provided in Appendix M. The Knowledge Resource Nomination Worksheet helped track selection criteria information, individuals' contact information, and follow-up communications. As a result of the participant solicitation process, 19 potential panelists responded. Four potential panelists who showed interest in the study declined to participate explaining the study time requirements and other personal commitments were factors they considered. Of the remaining respondents, six participants were selected for the Delphi panel.

To reduce the impact of organizational or individual biases, the participant acquisition was delimited to four experts who possessed at least 10 years expertise in project management and cost analysis for project planning. A further delimitation was the selection of one individual employed from a single company or industrial aviation site. Delphi expert panelists were selected from backgrounds, which included government agencies other than the FAA. Personnel employed by the FAA were excluded from the study because the FAA provides regulatory oversight for the industry and may have induced biases that could have threatened the validity of the study. Consideration was given to communications with panelists as to not intrude on their personal time but to keep them informed on the study progress. Follow-up e-mails were sent to panelists each round to elicit participation as suggested by Keeney (2010).

Materials/Instruments

The Delphi panel data collection instrument consisted of three questionnaires to which panelists are asked to respond, the first questionnaire being a seed questionnaire (see Appendix D). The open-ended seed questions of the first questionnaire were developed to address the research questions and allowed participants to respond to broad issues as suggested by Delphi method literature (Day, 1975; Delbecq et al., 1975; Keeney, 2010). The preliminary assessment was conducted to test the usability of the first questionnaire and the seed questions to address the research questions. Questionnaires were sent to experts in three rounds to collect their opinions regarding key factors such as business applications, labor standards and sources, schedule standards, and other information to be found in a decision support system framework for SMS cost estimation.

Data Collection, Processing, and Analysis

Data was collected from typed written responses from open-ended questions. The study included three Delphi rounds. Each round was briefly discussed below, followed by a discussion on data preparation methods.

Round 1 (solicit responses). An introduction to the Delphi Round 1 was sent via e-mail (see Appendix I) to each aviation expert with the purpose of the study, instructions for the first round of questions to solicit expert opinion, and the Round 1 questionnaire (see Appendix D). The instructions for Round 1 included a deadline for responses. In the first round, the Delphi method began with five open-ended questions to solicit expert opinion on the key factors in the use of a decision support system framework for SMS cost estimation. Round 1 of this study involved reaching an understanding of how the group viewed the issue. Open-ended questions allowed freedom of responses and panelists were encouraged to expand upon the seed questions (Keeney, 2010). Timely correspondence with the participants displays the sincerely of interest in their participation and enhances response rates (Delbecq et al., 1975; Kenney, 2010).

In some Delphi studies, personal contact was shown to stimulate a higher level of response (Frewer et al., 2011; Keeney, 2010). The questionnaire was sent to each expert the same day they agreed to participate in the study after qualification criteria was verified as suggested by Delbecq et al. (1975). The Round 1 questionnaire was in a Microsoft Word document format, which allowed experts to clarify or expand their responses. Round 1 is typically used to generate ideas (Efstathiou, Ameen, & Coll, 2008). Panelists were asked to clarify or expand their answers with additional responses to explain their opinions and, if possible, provide technical or scholarly references or expand on their past experience that supported their opinion. Experts were encouraged to suggest new questions or to modify existing questions. The results of the Round 1 questionnaire were prepared, duplicate items or themes consolidated, and provided to panelists as feedback for Round 2.

Round 2 (predictive). An introduction to the Delphi Round 2 was sent via e-mail (see Appendix J) to each expert with instructions for the second round, a response sheet of randomly compiled responses gathered from Round 1, and the Round 2 questionnaire (see Appendix N). The Round 2 questions were developed on the foundation of the responses from Round 1 and included six additional open-ended questions to expand upon ideas. One open-ended question was related to why the benefits of safety programs have been difficult to analyze and the barriers to provide a business case for safety programs. Five of the open-ended questions were related to SMS training. Panelists were given the opportunity to suggest new questions or modify existing questions. Responses from Round 1 considered outside the scope of the study were considered non-relevant and were not included in the Round 2 instrument. The format included a section that allowed the experts to clarify or expand their responses.

In addition to the feedback from Round 1 and the Round 2 Questionnaire, the Delphi panel was provided a SMS cost-estimating tool (see Appendix O) to stimulate group thinking and new contributions as suggested by researchers (Huff, Huff, & Thomas, 1992; Klenk & Hickey, 2011; Linstone & Turoff, 2011). According to Taleb (2010), some tools can lead to unexpected discoveries. The SMS cost-estimating tool included the scope of the ICAO SMS program model (to include cost and time) to assist in developing a decision support system for SMS cost estimation. The ICAO SMS program model work breakdown structure was transferred from the Gantt chart format to a Microsoft Excel spreadsheet to translate the ICAO SMS program model daily estimates into labor hours with corresponding costs. Microsoft Excel software is typically used to develop cost estimates building from the project WBS (FAA, 2012). The cost estimating tool did not include resource counts (number of personnel) that would perform the task-specific activities, costs related to different labor categories, SMS training duration time, or the number of personnel that would be expected to receive training, that would account for variables expected in cost estimation activities since this data was not provided in the ICAO SMS model. However, mathematical errors discovered while transcribing the data into Microsoft Excel was corrected in the cost estimation tool. The mathematical errors were coded in the Excel spreadsheet column titled *ICAO Model Error* and are discussed further in Chapter 4.

In Round 2, panelists were asked to respond by rating the importance of each of the statements and provide justification for the judgment. Ranking of key issues are typical in the safety field and Delphi applications (Biggs, Banks, Davey, & Freeman, 2013). Two scaling methods are commonly used in a Delphi: (1) simple ranking, and (2) Likert-type rating scale (Scheibe, Skutch, & Schofer, 1975). Survey questions 1 through 16 employed a common 5-point Likert scale, with choices ranging from: (a) strongly agree, (b) agree, (c) neither agree nor disagree, (d) disagree, or (e) strongly disagree, with the statements posed that closely represented their opinion. Panelists were asked to provide justification or additional comments for their opinions, if applicable.

Round 3 (stability). An introduction to the Delphi Round 3 was sent via e-mail (see Appendix K) to each expert with instructions for the third round, a response sheet of randomly compiled responses gathered from Round 2, the Round 3 questionnaire (see Appendix R), and a tool for modeling costs of SMS training (see Appendix Q). The format included a section that allows the experts to justify their responses. At the conclusion of the study, an e-mail (see Appendix S) was sent to each participant, thanking them for their contribution. Each panelist was provided the opportunity to be acknowledged in the final research document.

Processing. Gathering and transcribing the data facilitated qualitative data analysis by familiarization of the data (Rabiee, 2004; Shank, 2006; Silverman, 2010). Data from each round was collected in a Microsoft Word format, edited for duplicate responses, themes, and used to prepare the subsequent round of questions. Data was then transcribed into a Microsoft Excel spreadsheet to facilitate coding and data analysis following Saldaña (2013). The Microsoft Excel spreadsheet facilitated calculating frequency, percent of responses, and mapping to different panelist position, expertise, and type of operation. Data was categorized by themes (Delbecq et al., 1975) and coded by panelists number to show the responses of different stakeholders, because this data breakdown can prove to be significant when dealing with decision-making (Linstone & Turoff, 2011). According to Turoff (1975), tracking the responses of sub-groups is a mechanism to check if the background of the panelists reflects a particular view (Turoff, 1975).

Panelist. The name of the panelist was included for audit traceability; yet, de-identified in the study records. Panelists were coded (i.e., P1, where P1 equates to panelist 1) to exclude names.

R1Q1, R1Q2, R1Q3. Each round of questions was identified by the round and the question number (i.e., R1Q1, where R1 represented Round 1 and Q1 represented Question 1). Panelist responses to two-part questions were further coded for audit traceability (i.e., R1Q1-1, where represented then first part of the question and R1Q1-2 represented the second part of the question).

Response. Each participant's response was recorded for data analysis and audit traceability. Panelists responses were coded (i.e., P1-1, where P1 was equivalent to panelist 1 and -1 was the number of the response).

Response sheets. Responses for each round were randomly complied and used to create feedback to the Delphi panelists. Feedback included key factors for consideration and areas requiring further thought (Bolger & Wright, 2011). The feedback given to the panelists contained no statistical measures as suggested by the literature. However, feedback in the form of justifications for judgments was included as suggested by Bolger and Wright (2010). Responses containing personal information related to a panelist's position within their organization and information related to a panelist's expertise were deleted from the feedback to prevent informational social influence as suggested in the literature (Kerr & Tindale, 2011; Landeta & Barrutia, 2011). Responses considered incomplete or non-relevant for the purpose of the study were included in the feedback to panelists but were eliminated from the survey instruments. Panelist identity was not disclosed on the response sheet.

Analysis. Qualitative data analysis involved familiarization, identification, indexing, charting, and mapping. According to Ecken, Gnatzy, and von der Gracht (2011), researchers should be aware of potential consequences of the Delphi method such as desirability bias when interpreting their results. Gathering and transcribing the data facilitated qualitative data analysis by familiarization of the data (Rabiee, 2004; Shank, 2006; Silverman, 2010). Careful attention was placed on interpreting the results in order to answer the research questions and to ensure desirability biases were not induced (Ecken et al., 2011).

Methodological Assumptions, Limitations, and Delimitations

The advantages and limitations of the Delphi method were discussed in several recent studies and articles (Chang & Yang, 2010; Dalal, Khodyakov, Srinivasan, Straus, & Adams, 2011; Hasson & Keeney, 2011; Hung et al., 2008) and provided insight to overcome potential design weaknesses. Two limitations were identified in this study. The first limitation related to the process for the selection of experts who participated in this Delphi study. The process determined to select experts for participation is critical to any Delphi study and may contribute to the strengthening of the study's validity (Hallowell & Gambatese, 2010, Hung et al., 2008). Poor selection of participants may often weaken the research (Linstone & Turoff, 1975). To mitigate this potential weakness, the study design included the selection of experts who possessed at least 10 years expertise in project management and cost analysis for project planning. In addition, the selection draw came from personnel who worked at different companies and industrial aviation sites. Careful attention was placed on selecting Delphi expert panelists who had demonstrated an interest in SMS programs. Successful Delphi studies typically include participants who have a strong interest in the results of the study (Bolger et al., 2011; Linstone & Turoff, 1975).

The selection of the panel of four experts who participated in the Delphi portion of this research was based on the fulfillment of professional expectations that first, identified a historical of excellence in practice, and second, could bring to the research study one or more elements of expertise necessary for understanding the problem under study. It was assumed that the Delphi panelists participated with integrity and honesty and to the best of their abilities. It was also assumed that they offered and shared their knowledge withholding preconceptions and bias regarding the possibility of new approaches to the development of a decision support framework for addressing SMS program cost estimation.

In determining the study design, review of the various research approaches indicated that addressing the problem of the study required, in part, the availability of information that only a relatively small group of professionals possess. The study design included a preliminary assessment by industry professionals to identify expert criteria acceptable to represent the aviation industry as suggested by the literature (Bolger et al., 2011; Linstone & Turoff, 1975). To reduce the impact of organizational or individual biases, the participant acquisition was delimited to four experts who possessed at least 10 years expertise in project management and cost analysis for project planning. A further delimitation was the selection of one individual employed from a single company or industrial aviation site. Personnel employed by the FAA were excluded from the study since the FAA provides regulatory oversight for the industry and may have induced biases that could threaten the validity of the study. The second limitation of the study was the factor of time. In order to complete the Delphi rounds, the length of time required was expected to be 3-4 weeks as required for preparation and analysis (Hung et al., 2008). It was anticipated that this study would require approximately the same amount of time.

In order to narrow the scope of the study, the focus of the study was an exploration of decision-making frameworks for SMS cost estimation systems in the context exclusively identified in the ICAO SMS program model (2009) from the perspective of theory of quality management (Anderson et al., 1994). This scope was selected with reference to FAA guidance (DOT, 2010). In addition, the ICAO SMS program model included a work breakdown structure that was useful to identify key factors in the use of a decision support system framework.

Ethical Assurances

Strict adherence to federal regulations (45 CFR § 46) and the Northcentral University ethical policies were maintained throughout the study. Approval of the Northcentral University Institutional Review Board (IRB) was sought prior to any data collection. Four aviation management experts were enlisted to participate in the study as a Delphi panel. This volunteer panel was queried across three rounds of inquiry and their participation was ongoing for at five weeks. Throughout this time period and thereafter, all panelists were treated with the highest degree of professionalism. At no time were the responses of one panelist discussed with another panelist or outside colleague. This professional conduct was supported by the procedures of the Delphi technique.

Ethical considerations to ensure proper conduct toward the Delphi panelists included other assurances. Each Delphi panelist was asked to provide his or her e-mail address to expedite communications. Panelist anonymity was maintained at all times to prevent possible issues such as outside persuasion as well as to stimulate reflection and imagination (Linstone & Turoff, 1975). Data associated with panelists' responses was coded and only available to the researcher.

A letter of informed consent (see Appendix H) was distributed to each panelist prior to data collection with an assurance of confidentiality during and after the study would be maintained and no personnel information would be disclosed. The letter of informed consent included background information, procedure, confidentiality, voluntary nature of the study, risks and benefits of participation in the study, contact information, and statement of consent. In addition, panelists were advised they could withdrawal from the study at any time. The administration of informed consent occurred prior to data collection and supported assurances for ethical treatment of the study participants. Informed consent addressed several of the rights of the participants: the right to be informed, the right to confidentiality, and the right to be free from deception (Zikmund, 2003). Informed consent was obtained from each participant via e-mail correspondence prior to proceeding with any research.

Summary

The purpose of the qualitative study was to identify key factors to be found in a decision support system framework for SMS program cost estimation. The qualitative study included the development of a decision support system framework for SMS program cost estimation. The study sought to determine key SMS program cost parameters to provide decision makers with a framework for SMS program strategies.

The research method chosen for the study was a qualitative approach using a modified Delphi technique (Bolger & Wright, 2011; Grisham, 2009; Hallowell & Gambatese, 2010). The qualitative method was preferred over the quantitative method or mixed method as the qualitative methods allows for collecting open-ended data with the intent to develop themes (Teddlie & Tashakkori, 2009), and the qualitative Delphi study involved three rounds with a purposeful sample of four aviation management experts to develop a decision support system framework for SMS program cost estimation and a preliminary assessment to validate the survey questions. The design of the study was influenced by several researchers (Conboy, 2010; Deming, 1986; Patton, 2002; Zikmund, 2003) who emphasized the appropriateness of theoretical lenses and the use of person's knowledge in business that can provide different perspectives. Therefore, a qualitative modified Delphi approach was considered the best fit for the study.

Both academic and business experts have applied the Delphi method successfully in industries such as banking, education, IT, and quality management (Grisham, 2009). Several studies (Bolger & Wright, 2011; Ecken et al., 2011; Frewer, Fisher, Wentholt, Marvin, Ooms, Coles, & Rowe, 2011; Geist, 2010; Kim & Kumar, 2009) and literature on the Delphi method (Bolger, Stranieri, Wright & Yearwood, 2011; Hasson & Keeney, 2011; Keeney, 2010; Linstone & Turoff, 2011; Nowack, Endrikat, & Guenther, 2011; Parente & Anderson-Parente, 2011) were reviewed to apply lessons learned and develop the design for the study. The Delphi method is widely accepted as a research process to obtain accurate group consensus decisions or stability of responses (Chang & Yang, 2010; Duru et al., 2012; Linstone & Turoff, 2011).

In summary, the research method and design for the study were explained including details relating to the participants, materials/instruments, and the data collection, processing, and analysis. The methodological assumptions, limitations, and delimitations of the study were identified with reference to recent literature (Chang & Yang, 2010; Dalal, Khodyakov, Srinivasan, Straus, & Adams, 2011; Hasson & Keeney, 2011; Hung et al., 2008). The ethical assurances that were taken during the study to complied with NCU standards to ensure the ethical conduct toward Delphi panelists.

Chapter 4: Findings

The purpose of the current qualitative study was to identify key factors in a decision support system framework for SMS program cost estimation. The qualitative study included the development of a decision support system framework for SMS program cost estimation. The study involved a modified Delphi technique to allow for a panel of aviation industry experts to contribute a critical knowledge base to the study and sought to determine key SMS program cost parameters to provide decision makers with a framework for SMS program strategies.

Panelists were asked to refer to the ICAO SMS model to facilitate thinking to develop a decision support system framework for SMS program cost estimation. The descriptive responses of the Delphi panelists identified key factors in the development of a decision support system for SMS cost estimation and described how to model SMS project cost estimates using existing information sources in the aviation business environment. Chapter 4 contains the results and findings of each round of data collection based of the research and methodology presented in chapters 1, 2, and 3. First, the results of participant recruitment and each round are discussed; then, the findings of all three rounds are charted, mapped, and summarized. Chapter 4 is concluded with an evaluation of the findings compared to the key findings of major studies in the literature review, followed by a summary of the chapter.

Results

Q1. What do experts in the aviation industry perceive are the key factors in the development of a decision support system for SMS cost estimation?

The expert panel identified nine key factors for the development of a decision support system for SMS cost estimation that included: (a) regulations, (b) scope of work, (c) size of an organization, (d) WBS, (e) financial schedules, (f) cost analysis, (g) cost benefit analysis, (h) demonstrate implementation, and (i) training. The key factors were the results of panelist responses to four seed questions in the first round of the study, which were analyzed to identify main themes and the responses to questions posed in round two that stood out as key factors. In Round 3, panelists ranked the importance of each factor, for the development of a decision support system for SMS cost estimation, answering Research Question 1. The evaluation of the findings was compared to the key findings of major studies in the literature review.

Q2. How can SMS project cost estimates be modeled using existing information sources in the aviation business environment?

The descriptive responses of the panelists identified existing information sources in the aviation business environment to model SMS project cost estimates. The key factors previously discussed provided the baseline to understand how SMS project cost estimates be modeled using existing information sources in the aviation business environment. A high-level framework was developed for SMS cost estimation modeling that could be used by leaders of any organization. The framework consisted of information and tools one would expect in a decision support system for SMS cost estimation, specifically, the tools for program cost estimation, data sources and knowledge of training standards as perceived by experts that could assist decision makers with program development strategies. The high-level framework included:

- Key factors for a decision support system framework.

- Knowledge of scope of work.
- Knowledge of tools that could be used in cost estimation methods.
- Knowledge of data sources that could be used in cost estimation methods.
- Knowledge of size of organization to understand resources.
- Knowledge of training standards of stakeholders.

The high-level framework was discussed further in evaluation of the findings, and areas of agreement and disagreement with modeling strategies identified by the panelists with approaches in the literature review were discussed in evaluation of findings where modifications are warranted.

Managers at 15 professional organizations were asked to sponsor the study by posting the study announcement and participant recruitment solicitation on their websites, and a participant recruitment solicitation was posted on the FAA Facebook blog. Of the 15 managers at these organizations, four responded to the request, and one manager forwarded the recruitment solicitation via e-mail to that organization's members in four separate newsletters (equivalent to 4 days). As a result of the participant recruitment, six panelists met the selection criteria and consented to participate in the study; however, two panelists did not return the Round 1 questionnaire. Four panelists completed the first two rounds of the survey. Three of the four panelists completed all three rounds of the survey.

Demographic characteristics. The study sample consisted of a purposeful sample of four participants who were aviation management experts in project management and cost analysis for project planning and participated across three rounds of structured inquiry procedures. Panelists reported their specific position within their company such as first-line specialist (25%), middle management (25%), upper management (50%), and academic (25%). The demographic data of all four panelists included multiple aviation industry sectors and types of operations such as Part 91, general aviation (50%), Part 141, pilot school (50%), Part 142, training center (25%), government agency (25%), academic (25%), and professional safety consultant (50%). Panelists reported their specific area of expertise, which included multiple backgrounds within different domains. Categories of panelists' areas of expertise in the aviation industry were reported as airport operations (75%), engineering (75%), flight operations (100%), management (75%), quality (50%), and safety (75%). Of the four panelists with airport operations expertise, none identified their type of operation as Part 139, airport operations (0%). Panelists reported years of experience in the aviation industry as 15-19 years (25%) and more than 35 years (75%). Panelists' length of experience in project management and cost analysis was 15-19 years (50%) and 20-24 years (50%). Frequency tables for demographic characteristics of the Delphi panel appear in Appendix L.

Round 1 (solicit responses). Round 1 of the Delphi study took place between December 13, 2012, and January 5, 2013. Three weeks were allowed for Round 1 to facilitate the personal schedules of the panelists during the holiday season. The Round 1 questionnaire was sent to six experts to collect their opinions regarding key factors to be found in a decision support system framework for SMS cost estimation.

Two of the six panelists responded prior to the target date for completion, which assisted expediting data analysis. Of the six panelists who consented to participate in the study, four responded to the Round 1 survey. At the close of Round 1, the four panelists had provided 93 open-ended responses. Seven of the responses were related to new questions or modifications to existing questions, leaving 86 responses. Responses of the panelists were categorized by similarity and frequency counts appear in Table 3.

Table 3

Round 1 Results: Frequency of Items by Panelist

Panelist	Cost estimation tools	Labor standards and sources	Schedule standards	Key information prior to SMS implementation
P1	16	3	3	7
P2	3	2	2	5
P3	3	3	1	7
P4	18	2	2	9
Total responses	40	10	8	28

Sub-groups of the panel were categorized by type of position held within their organization and included first-line specialist, middle management, upper management, and academic. The frequencies of responses by panelists' type of position were summarized in Table 4. In addition, sub-groups of the panel were categorized by type of expertise and included airport operations, engineering, flight operations, management, quality, safety, and training. The demographic data of three panelists included aircraft certification (1), human factors (1), training (1), and weather (1) were not categorized as they were considered to be within the quality or safety domain. The frequencies of responses by panelist expertise are summarized in Table 5.

Table 4

Round 1 Results: Frequency of Items by Panelists' Position Within Their Organization

Position	Cost estimation tools	Labor standards and sources	Schedule standards	Key information prior to SMS implementation
First-line specialist	3	3	1	7
Middle management	3	3	1	7
Upper management	19	5	5	12
Academic	18	2	2	9
Total responses	40	10	8	28

Note. Data accounts for panelists with multiple positions.

Table 5

Round 1 Results: Frequency of Items by Panelist' Expertise

Expertise	Cost estimation tools	Labor standards and sources	Schedule standards	Key information prior to SMS implementation
Airport operations	37	5	5	16
Engineering	37	7	7	21
Flight operations	40	7	7	21
Management	37	7	7	21
Quality	34	5	5	16
Safety	37	7	7	21

Note. Data accounts for panelists with multiple backgrounds and disciplines.

Measures of central tendency of Round 1 responses appear in Table 6. The range of responses of the cost estimation tools needed for SMS cost estimation modeling was between 3 and 18 responses. The mean response per panelist was 10. The range of responses of the labor sources needed for SMS cost estimation modeling was two to three responses. The mean response per panelist was 2.5. The range of responses of the schedule modeling was two to three responses. The mean response per panelist was 1.8. The range of responses of key information needed for decision makers prior to SMS implementation was three to seven responses. The mean response per panelist was 4.8.

Table 6

Round 1 Results: Measures of Central Tendency

Measure of central tendency	Cost estimation tools	Labor standards and sources	Schedule standards	Key information prior to SMS implementation
Minimum responses	3	2	2	4
Maximum responses	18	3	3	9
Mean responses	10	2.5	1.8	4.7

The Round 1 questionnaire included five seed questions to solicit expert opinion on the key factors in the use of a decision support system framework for SMS cost estimation. One open-ended question solicited expert opinion of information a decision maker would be interested in knowing before implementing a safety management program. The Delphi panel had the opportunity to raise new questions and modify existing questions. Discussions regarding the seed questions and the results of the Round 1 survey follow.

In response to Round 1 seed Question 1, the Delphi panelists identified the tools expected to be used to assist in the development of a decision support system for SMS cost estimation. The purpose of this question was to understand the types of tools that individuals used in cost estimation activities. Of the 40 responses to seed Question 1, 20 responses were found relevant to the current study. The panelists identified 16 tools to assist in developing a decision support system for SMS cost estimation (see Table 7). The nine common themes of the tools were as follows: (a) program design, (b) process management, (c) scope of work, (d) industry best practices, (e) IT, (f) resources, (g) modeling, (h) regulatory requirements, and (i) user implementation tools. The themes related to tools are presented in Table 8.

Table 7

Round 1 Results: Tools for SMS Cost Estimation by Frequency

Tools for SMS cost estimation models	Frequency	Percentage
Internal reporting programs (flight assessment, hazard reporting systems, and internal evaluation programs)	**4**	**100**
Cost analysis	**2**	**50**
SMS training	**1**	**25**
Work Breakdown Structure (WBS), scope of work	1	25
Project Analysis Resource Tool (PERT)	1	25
Microsoft Excel	**1**	**25**
Microsoft Project	**1**	**25**
Regulatory requirements	**1**	**25**
Size of operation	1	25
FAA SMS material	1	25
Cost benefit analysis	**1**	**25**
Calendar	1	25
Experts, company knowledge	1	25
Metrics	1	25
Self-developed programs	1	25
Similar complex projects	1	25

Note. Multiple responses reported for other questions are shown in boldface.

Table 8

Round 1 Results: Themes Associated With Tools for SMS Cost Estimation

Theme	Examples
Program design	Cost/benefit analysis; one might examine similarly complex projects; internal evaluation program; flight risk assessment tools; pragmatic safety measures, if not determined properly, can exhaust organization budgets; metrics on past accidents and incidents.
Process management	Cost analysis; comparing the cost associated with an incident and/or accident; change management.
Scope of work	Scope (WBS), time, and cost breakdown; size of operation; scope, scalability, and implementation of SMS.
Industry best practices	Sharing industry best practices are tools that should be used; a Project Evaluation and Review Technique analysis includes three time estimates for each activity: optimistic, most likely, and pessimistic. This enables the generation of comparative paths.

Information technology	Off-the-shelf programs; Microsoft Excel spreadsheet; Microsoft Project Manager that include Scope (WBS), time, and cost breakdown.
Resources	Experts, company knowledge.
Modeling	A small operator is most likely to use a calendar.
Regulatory requirements	It is very important to differentiate the regulatory requirements, size of operation, and motivation of decision makers in assessing the scope, scalability, and implementation of SMS.
User implementation tools	Self-developed programs; FAA SMS material.

In response to Round 1 Question 2, the Delphi panelists identified the labor standards and sources of information expected to be used to develop a decision support system for SMS cost estimation. Panelists provided ten responses, of which one response was irrelevant to the study. Responses were categorized into three common themes and reported in Table 9. The categories were: (a) data sources, (b) regulatory requirements, and (c) process management. Of the panelists, 75% identified data sources.

Table 9

Round 1 Results: Themes Associated With Labor Standards and Sources

Theme	Examples
Data sources	U.S. Department of Labor; collective bargaining agreements are used plus impact and implementation considerations; non-collective bargaining agreement personnel (i.e., non-hourly salary-based personnel) usually have a different labor standard.
Regulatory requirements	U.S. Department of Labor.
Process management	Each company should have its own labor standards and practices that align with federal/state laws.

In response to Round 1 Question 3, the Delphi panelists identified schedule standards, in the context of labor hours, expected to be used to develop a decision support system for SMS cost estimation. Panelists provided eight responses. One response was irrelevant to the study and was eliminated. Responses were categorized into four common themes and reported in Table 10. The categories were: (a) modeling methods, (b) resources, (c) data sources, and (d) regulatory requirements.

Table 10

Round 1 Results: Themes of Schedule Standards

Theme	Examples
Modeling methods	Usually the 40 hour/week schedule; labor hours...hard to say but probably 6-8 weeks in orientation time and 6 months in implementation; there may be a wide variance of scheduling standards between what large companies and small companies would use determining scheduling costs.
Resources	Reality of finite resources readily available to commit; any commonly available business and user-friendly calendar/ scheduling software.
Data sources	A pay schedule would be used for each company.
Regulatory requirements	Title 14, Code of Federal Regulations, Part 121.471.

Delphi panelists were asked what other information a decision maker responsible for the implementation of a SMS program in the aviation industry would be interested in knowing before implementing a SMS program. Panelists provided 28 responses that were categorized into 11 themes: (a) cost analysis, (b) cost benefit analysis, (c) data sources, (d) industry best practices, (e) leadership, (f) modeling, (g) program design, (h) regulatory requirements, (i) resources, (j) responsibilities, and (k) scope of work. Table 11 contains examples of the themes.

Table 11

Round 1 Results: Themes of Information a Decision Maker Would Be Interested in Prior to SMS Implementation

Theme	Examples
Program design	Desired outcomes; ease of use.
Industry best practices	Information that would not cause a company or personnel not to reinvent the wheel; industry based best practices would be the first place I would look to obtain information; SMS training but there is not a clear or specific discussion of industry best practices; customer support.
Leadership	The support of such a program must come from the CEO of the company, air carrier, and so forth. Unless a SMS is endorsed by leadership, no one will take it seriously; the safety manager should report directly to the division vice president. Otherwise, no one will listen if the position is the same level as other managers (i.e., engineering, sustainment, and so forth).
Modeling	Time commitments, implementation time; results and or outcomes to include cost and expenses.
Cost analysis	Resource costs; it all comes down to money. An extensive cost analysis should be conducted. Financially demonstrating that a pro-active safety program will boost the bottom-line will convince leadership to implement such a program.
Cost-benefit analysis	A cost-benefit analysis would be extremely nebulous. Short-term, or even long-term wins can be wiped out with one event.
Data sources	Government and safety nongovernment organizations that acquire and analyze safety data.
Regulatory requirements	What is expected by the state.
Resources	The players: (a) primary customers/users/funds sources; (b) stakeholders; (c) other interested parties. What assumptions have the primary customers, users, funds sources, stakeholders, and other interested parties and organizations already made?
Responsibilities	Performance in the context of who will do what, and when.
Scope of work	This [context unknown] is a very important piece of the safety systems implementation process. Recognizing this is an academic exercise to justify time commitments and costs, the scope of the research process cannot be conducted in an isolated or pristine environment.

In response to Round 1 Question 5, concerning what new questions or modifications of existing questions participants would recommend for this study, four panelists provided seven responses. Two responses were irrelevant to the study. One panelist provided additional discussion related to Round 1, Question 3, which indicated the question needed modification. One new question related to leadership was suggested: Is SMS an integral component of a business as financial planning? The intent of this question would be to determine if company leaders are providing the same financial support for safety programs as they would for other budget requirements within the organization. This question was inappropriate for the current study and may be more appropriate for a study on the relationship of an organization's safety culture and financial expenditures on safety programs.

Additional topics for discussion were categorized into three categories: (a) cost analysis, (b) modeling, and (c) resources. Items related to cost analysis included two topics: (a) making a connection between risk or risk mitigation efforts and costs or cost analysis and (b) the need to meet ever changing upcoming FAA requirements. Financial risk to an organization was of interest in this study; however, risk or risk mitigation related to cost analysis was not within the scope of the study. The discussion for schedule modeling was related to an example of an aviation organization that did not have an existing SMS program in which the allocation of resources and time considerations were predetermined by decision makers. Resources and time considerations for program schedule were considered key factors of a decision support system for SMS cost estimation that influenced six new questions for Round 2.

At the end of Round 1, a SMS Cost Estimation Tool (see Appendix O) was developed by transferring the ICAO SMS program model WBS into a Microsoft Excel format, as researchers have typically used Microsoft Excel to develop cost estimated building from the project WBS (FAA, 2012b). Secondary data were in the form of 102 work tasks in the ICAO SMS program model (ICAO, 2009). Specific data transcribed included the SMS phase task name and estimated duration (days). Mathematical errors discovered after transcribing the data to Microsoft Excel were corrected.

To translate work task time into labor costs, an arbitrary labor cost of $48 per labor hour was assumed in the SMS Cost Estimation Tool. A cost of $48 per labor hour was influenced by the wage per labor hour cost used in the NPRM (FAA, 2010d) for the Implementation Plan, specifically, the *SMS Documentation (Initial Hourly Burden)* and the *Estimated Implementation Costs*. Estimated duration, Columns A through E in the Excel spreadsheet, included corrections for mathematical errors discovered when the data was transcribed. The SMS Cost Estimating Tool did not include resource counts (number of personnel) that would perform the task-specific activities, costs related to different labor categories, SMS training duration time, or the number of personnel expected to receive training that would account for variables in cost estimation activities because the ICAO SMS model did not include these data. After corrections, a total of 2,803 days or 22,424 labor hours were determined to be an adequate representation of the work tasks necessary to accomplish cost estimation activities following ABC principles for all four phases, assuming only one person performed each task. The results of transcribing the data and adding cost elements are summarized in Table 12.

Table 12

Results of SMS Cost Estimation Tool Development

ICAO SMS model		Study model			
Phase	Days[a]	Days[b]	Labor hours[c]	Cost per hour[d]	Cost[e]
Phase 1	157	339	2,712	$48.00	$130,176
Phase 2	287	634	5,072	$48.00	$243,456
Phase 3	445	1010	8,080	$48.00	$387,840
Phase 4	341	820	6,560	$48.00	$314,880
Total	1230	2803	22,424[f]		$1,076,352[f]

Note. Phase refers to the ICAO SMS model.
[a]A summary of all four phases of the ICAO SMS model data transcribed were reported in days. Adapted from *Safety management manual (SMM)* by International Civil Aviation Organization, 2009 (Doc 9859, 2nd ed.), pp. 10-APP 2-11 through 10-APP 2-14. Copyright 2009 by International Civil Aviation Organization. Adapted with permission. [b]Data were the results of transcribing 102 work tasks from the ICAO SMS model to a Microsoft Excel spreadsheet to create a SMS Cost Estimation Tool (see Appendix O). Data represents corrections for mathematical errors discovered after transcribing the data. [c]Labor hours were the results of converting days to hours (1 day = 8 hours). [d]Average labor cost of $48 per hour assumed for all labor categories (adapted from "Notice of proposed rulemaking (NPRM)" [Docket Number FAA- 2009- 0671], by Federal Aviation Administration, 2010, *Federal Register*, p. 68224-68245). [e]Data were the results of calculating the labor hours for each phase multiplied by an average cost of $48 per labor hour. [f]Labor and cost estimates account for only 720 hours of training.

Round 2 (predictive). Round 2 of the Delphi study took place between January 16, 2013, and January 22, 2013. In Round 2, the panelists rated each of the responses provided in Round 1 survey and provide justifications or clarification comments. Panelists rated their agreement with the tools expected to be used to assist in the development of a decision support system for SMS cost estimation. Panelists rated their level of agreement with labor and schedule standards and sources of information expected to be used to develop a decision support system for SMS cost estimation. Panelists were asked to rate their level of agreement with information a decision maker responsible for the implementation of a SMS program in the aviation industry may be interested in knowing before implementing this type of program. One panelist returned the survey prior to the target date, which accelerated the time for data analysis. All four panelists provided responses at the end of Round 2.

Responses to the Round 2 survey instrument were analyzed to begin the stability process. Because the foundation of the Delphi study was panelist anonymity and statistical data were not provided as feedback, panelist responses were not influenced by panelist names, titles, position dominance, or confidence levels.

Panelists rated their agreement to statements built on the responses of open-ended questions from the Round 1 instrument. Specifically, panelists rated their agreement with the cost estimation tools, labor standards and sources, and schedule standards expected to be used to assist in the development of a decision support system for SMS cost estimation. Panelists also rated their agreement with information that decision makers would be interested in prior to implementing a SMS program. The Round 2 data collection instrument included 34 questions. In Round 2, participants identified areas of agreement and disagreement with 151 justification comments and responses provided by the panelists.

In Round 2, Questions 1 through 16 were statements related to tools the panelists would expect to use in a decision support system for SMS cost estimation. Survey Questions 1 through 16 included a common 5-point Likert-type scale, with choices ranging from: (a) *strongly agree*, (b) *agree*, (c) *neither agree nor disagree*, (d) *disagree*, or (e) *strongly disagree*, with the statements posed that closely represented their opinion. Panelists provided justification or additional comments for their opinions, if applicable. The panelists provided 68 justification comments related to tools.

Round 2 Question 1 asked panelists their opinions on a statement related to the significance of the WBS, specifically if the WBS provides the scope of work necessary to accomplish cost and schedule estimations. Fifty percent of the participants strongly agreed with the statement, and 50 % neither agreed nor disagreed (see Table 13). Panelists provided four comments for Question 1. Justifications for strongly agree included, "WBS is one of the better comprehensive tools" and "however, it is the WBS designer's view, not necessarily what will actually occur." Justifications for neither agree nor disagree included the WBS is a "labor model of the program. It depends upon the structure of the program."

Table 13

Round 2 Question 1 Results: Work Breakdown Structure

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
50%		50%			4	50%

Round 2 Question 2 asked panelists whether the regulatory requirements are important in assessing the scope, scalability, and implementation of SMS. The responses ranged across the scale with 25% in agreement, 25% neither agreed nor disagreed, 25% disagreed, and 25% strongly disagreed with the statement (see Table 14). Participants provided eight justification comments for Question 2. Panelist justification for agreement with the statement included, "the regulatory requirements provide the foundation" whereas justifications for strongly disagree included "Current regulatory requirements need to examined and be prepared for deep systemic and organizational change." In response to justifications for neither agree nor disagree with the statement that regulatory requirements are important in assessing the scope, scalability, and implementation of

SMS, panelists posited regulations are "bare minimums, not best practices." The remaining comments related to program process management and were not within the scope of the purpose of this study.

Table 14

Round 2 Question 2 Results: Regulatory Requirements

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	25%	25%		25%	8	25%

In response to Round 2 Question 3, the study group (100%) agreed or strongly agreed the size of the operation was important in assessing the scope, scalability, and implementation of SMS (see Table 15). Panelist justifications for strongly agree included, "Specifically the scope and the scale, however NOT the implementation." One justification comment was not within the scope of this study.

Table 15

Round 2 Question 3 Results: Size of Operation

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
25%	75%				2	100%

Of the responses for Question 4, 75% of the panelists believed an extensive cost analysis should be conducted prior to implementing a safety program to understand expenses and demonstrate benefits (see Table 16). Justification with agreement indicated a cost analysis would highlight priorities and is an "interactive process to be repeated after significant changes." As justifications for strongly disagree, panelists posited "some of the existing cost predictions would scare off event *[sic]* the most enthusiastic safety champion." Disagreement justifications indicated a "rough order of magnitude (ROM) would be more appropriate" than an extensive cost analysis, which indicated the question needed modification, specifically, the exclusion of the word *extensive*. Remaining comments were panelist opinions of the value of SMS programs in the aviation industry and not within the scope of this study.

Table 16

Round 2 Question 4 Results: Cost Analysis

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	50%		25%	25%	6	50%

Round 2 Question 5 asked the panelists' opinion if an extensive cost-benefit analysis should be conducted prior to implementing a safety program in order to understand expenses and demonstrate benefits. This question was somewhat similar to Question 4 but was separated into two questions as several panelists used both cost analysis and cost-benefit analysis as though they had the same meaning. Included in this question were responses from Round 1, which included two additional statements: (a) it was noted that the ICAO SMS document did not include cost/benefit as an item in the SMS implementation plan, and (b) a cost-benefit analysis would be extremely nebulous; a short-term, even long-term, wins can be wiped out with one event. Of the panelists, 50% agreed, 25% neither agreed nor disagreed, and 25% disagreed with the statement (see Table 17). Panelists' justification for agreement indicated "one needs to include the assumptions and expectations under which the process was conducted" and "whether a cost-benefit analysis should be conducted is a decision for the organization that will be implementing the safety program. It is not a safety item." Justification for disagreement,

included "It is not a nebulous process." Responses from the panelists in Round 2 indicated the question needed to be modified, specifically, elimination of the word *extensive* in the statement.

Table 17

Round 2 Question 5 Results: Cost-Benefit Analysis

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	50%	25%	25%		6	50%

Round 2 Question 6 asked the panelists' opinion whether a statement related to Microsoft Excel software can be used to develop cost estimates building from the project WBS. This question was included in the second round based on the responses of a seed question asking panelists what tools they would expect to use to develop a decision support system for SMS cost estimation. Half (50%) of the panelists were in agreement with the statement, whereas 50% neither agreed nor disagreed (see Table 18). One justification for agreement was judged to be appropriate for Question 7, specifically, "there is another commonly available software called MS PROJECT that might be better for mapping out the timelines, jobs and responsibilities." Justification for neither agree nor disagree included, "Depends on the size, scope, and scale."

Table 18

Round 2 Question 6 Results: Microsoft Excel

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	50%	50%			2	50%

Round 2 Question 7 asked the panelists opinion of a statement whether Microsoft Project software can be used to develop cost estimates building from the project WBS. Half (50%) of the panelists were in agreement with the statement, whereas 25% strongly agreed and 50% neither agreed nor disagreed (see Table 19). Panelists provided two comments to this question.

Table 19

Round 2 Question 7 Results: Microsoft Project

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
25%	25%	50%			2	50%

Round 2 Question 8 asked expert opinions of the statement self-developed programs are tools one would expect to use in a decision support system for SMS cost estimation. Half (50%) of the panelists were in agreement with the statement, and 50% neither agreed nor disagreed (see Table 20). The panelists provided three comments to this question. In general, panelists posited "self-developed programs are appropriate when explained."

Table 20

Round 2 Question 8 Results: Self-developed Programs

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	50%	50%			3	50%

Round 2 Question 9 asked expert opinions on the statement a PERT analysis and sharing industry best practices are tools one would expect to use in a decision support system for SMS cost estimation. Of the responses, 75% of the panelists were in

agreement with the statement, and 25% disagreed with the statement (see Table 21). Panelists justification for agreement indicated "a Project Evaluation and Review Technique (PERT) analysis includes three time estimates for each activity- optimistic, most likely, and pessimistic. This enables the generation of comparative paths." Panelists' justification for disagreement indicated, "PERT is a scheduling tool, not cost estimation. PERT is used to crash/rush the project. Crashing will drive costs up."

Table 21

Round 2 Question 9 Results: PERT and Sharing Industry Best Practices

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	75%		25%		2	75%

Question 10 asked for organizations that have limited financial resources and indicated a calendar may be used as a tool for project planning. Of the responses, 75% were in agreement with the statement, and 25% neither agreed nor disagreed (see Table 22). In general, the panelists agreed that a calendar was a useful tool. Panelists' justification for agreement included, "This is a building block project and while some projects are simultaneous, others require completion before moving forward." Additional tools indicated by the panelists included templates a small organization should be able to download and a white board with specific tasks to be completed as opposed to specific dates.

Table 22

Round 2 Question 10 Results: Calendar as Tool for Project Planning

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	75%	25%			5	75%

Round 2 Question 11 asked if experts and company knowledge are tools one would expect to use in a decision support system for SMS cost estimation. Of the responses, 75% of the panelists either strongly agreed or agreed with the statement, whereas 25% neither agreed nor disagreed (see Table 23). Justifications for agreement included the "need to understand the company's priorities" and "the key component to the successful implementation of a SMS is 'buy-in' from all levels of the company." Justifications for neither agree nor disagree included, "If the experts really are recognized in their field."

Table 23

Round 2 Question 11 Results: Experts and Company Knowledge

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
50%	25%	25%			6	75%

Round 2 Question 12 asked if FAA SMS material is a tool one would expect to use in a decision support system for SMS cost estimation. Seventy-five percent of the panelists strongly agreed or agreed, whereas 25% strongly disagreed (see Table 24). Panelist justification for agreement included, "Gap analysis tools need to be enhanced by FAA to make them more user friendly" and "provides baseline requirements to include in the analysis" or crosschecks. Justification for strongly disagree included, "I have not read any FAA SMS material that had valid cost estimations and those mentioned in the NPRM did not have c [*sic*] breakdown available for analysis. The numbers used by the FAA would scare off most owner/managers."

Table 24

Round 2 Question 12 Results: FAA SMS Material

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
25%	50%			25%	6	75%

Round 2 Question 13 asked if flight assessment, hazard reporting systems, and internal evaluation program are tools one would expect to use in a decision support system for SMS cost estimation. Of the panelist responses, 75% either strongly agreed or agreed, whereas 25% neither agreed nor disagreed (see Table 25). Justification comments for agreement indicated "there would need to be a methodology for extracting, qualification and quantification of data." Panelist justification for neither agree nor disagree suggested, "I would assess the predicted scope of the programs to ascertain costs of the entire program but not as standalone."

Table 25

Round 2 Question 13 Results: Internal Programs

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
25%	50%	25%			3	75%

Question 14 asked if metrics are tools one would expect to use in a decision support system for SMS cost estimation. Three fourths (75%) of the panelists were in agreement with the statement, whereas 25% neither agreed nor disagreed (see Table 26). Panelists provided five comments to this question. All of the responses to program design, specifically, specifically, to performance and quality control, and were not within the scope of this study.

Table 26

Round 2 Question 14 Results: Metrics

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	75%	25%			5	75%

Round 2 Question 15 asked if similar complex projects are tools one would expect to use in a decision support system for SMS cost estimation. Of the responses, 75% of the panelists were in agreement with the statement, whereas 25% strongly disagreed (see Table 27). Justification comments for strongly disagree included,

> SMS can cost whatever is committed to the project (within parameters, obviously). The success of the SMS may vary due to lack of funds committed however there is still no direct correlation between SMS and prevention of an accident. Data is still speculative and hopeful.

Table 27

Round 2 Question 15 Results: Similar Complex Projects

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
	75%			25%	4	75%

Round 2 Question 16 asked panelists' opinions if SMS training is a tool they would expect to use in a decision support system for SMS cost estimation. Of the responses, 75% of the panelists were in agreement and 25% neither agreed nor disagreed with the statement (see Table 28). Justification for agreement included a "baseline understanding is necessary" and "training is organic to understanding and success." Justification for neither agree nor disagree included, "I would assess the predicted scope

of the programs to ascertain costs of the entire program but not as standalone."

Table 28

Round 2 Question 16 Results: SMS Training Tool

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
25%	50%	25%			3	75%

The next six questions asked the panelists to rate their level of agreement with the labor and schedule standards one would expect to uses to develop a decision support system for SMS cost estimation. The survey questions employed a Likert-type scale, with choices ranging from: (a) *not important*, (b) *somewhat important*, (c) *very important*, or (d) *critical*, with the statements posed that closely represented their opinion.

Round 2 Question 17 asked panelist opinions if collective bargaining agreements were sources of data that one could use for program cost estimation modeling. Three fourths (75%) of the panelists believed collective bargaining agreements were somewhat important, whereas 25% believed they were not important for program cost estimation modeling (see Table 29). Justifications for the somewhat important responses indicated collective bargaining agreements were important sources of data that one could use for program cost estimation modeling "when a factor for the company or operation" and "depends on CBA [collective bargaining agreements] impact for I & I [Impact and Implementation]." Panelists did not provide justification comments for not important.

Table 29

Round 2 Question 17 Results: Collective Bargaining Agreements

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
25%	75%			3	75%

Round 2 Question 18 asked if company standards are sources of data that one could use for program cost estimation modeling. Half (50%) of the panelists indicated company standards were very important, whereas the other half (50%) believed they were somewhat important (see Table 30). In general, panelist justifications for the importance included company standards were "realistic source of information."

Table 30

Round 2 Question 18 Results: Company Standards

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
	50%	50%		2	100%

Question 19 asked if the BLS financial schedules were sources of data one could use for program cost estimation modeling. Three fourths (75%) of the panelists indicated the financial schedules provided by the U.S. Bureau of Labor were not important sources of data one could use for program cost estimation modeling, whereas 25% thought they were very important (see Table 31). Panelist justification for not important indicated the financial schedules were "non-industry specific, geographically broad, and often erroneous or not current." Panelists did not provide justification comments for very important.

Table 31

Round 2 Question 19 Results: U.S. Bureau of Labor and Statistics Financial Schedules

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
75%		25%		1	75%

Round 2 Question 20 asked if the labor hours for the safety officer are sources of data that one could use for program cost estimation modeling. The question was posed in to understand panelists' opinion on why the labor hours for a safety officer were considered more important than those of other labor categories. Of the responses, 75% of the panelists believed labor hours for the safety officer were somewhat important sources of data that could be used for program cost estimation modeling, whereas 25% believed they were not important (see Table 32). Panelist justification for somewhat important included,

> Good for baselining. My thinking is that the Safety Office or whomever does the cost/benefit analyses may use labor hours projected with SMS implementation as a baseline or baselining to visualize the economic impact. The labor hours information would be obtained probably from the Human Resources or Budget departments.

Panelist justification for not important included, "Would be assigned during the project build."

Table 32

Round 2 Question 20 Results: Safety Officer Labor Hours

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
25%	75%			4	75%

Round 2 Question 21 asked if public labor laws are sources of data that could be used for program cost estimation modeling. Half (50%) of the panelists indicated public labor laws were not important, whereas 50% believed they were somewhat important (see

Table 33). One justification was provided for this question and was judged more appropriate for Question 22.

Table 33

Round 2 Question 21 Results: Public Labor Laws

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
50%	50%			1	50%

Round 2 Question 22 asked panelists' opinions of the statement if Title 14 Code of Regulations, Part 121.471, Flight time limitations and rest requirements: All flight crewmembers, is a source of data that one could be used for program cost estimation modeling. Of the responses, 100% of the panelists believed this regulation was either very important or somewhat important and was a source of data that could be used for program cost estimation modeling (see Table 34). Justification for somewhat important included, "Obviously most companies choose to be in compliance . . . better include new FAA Crew/duty rest times as well– safety reports, etc. will be part of extending or adding duty time."

Table 34

Round 2 Question 22 Results: Title 14 Part 121.471 as Source of Data

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
	75%	25%		1	100%

Panelist responses to Round 1, Question 4 and Round 2, Questions 1, 20 and 25 influenced further investigation of data sources. In order to delve deeper into existing data sources, data were drawn from the BLS financial schedules for the air transportation industry NAICS Code 481100 for scheduled (BLS, 2012a) and Code 481200 non-scheduled (BLS, 2012b) (see Appendix P). Data drawn from the BLS financial schedules consisted of the mean hourly wages and mean annual salaries of 16 labor categories for scheduled air transportation and 12 labor categories for non-scheduled air transportation. The mean hourly wage of the 16 labor categories selected for scheduled air transportation code 481100 was $41.39 (not including benefit costs). Using an average benefit rate of 25%, the mean hourly wage of the same 16 labor categories was $51.74. The mean hourly wage of the 12 labor categories selected for non-scheduled air transportation Code 481200 was $40.07 (not including benefit costs). Using an average benefit rate of 25%, the mean hourly wage of the same 12 labor categories was $50.09. Examples of data provided by the BLS are provided in Appendix P.

For the next five questions, panelists rated level of agreement with information a decision maker responsible for the implementation of a SMS program in the aviation industry may be interested in knowing before implementing this type of program. Round 2 Question 23 asked if leadership roles are tools for implementing a SMS program. Of the responses, 100% of the panelists indicated leadership roles were critical or very important tools for implementing a SMS program (see Table 35). Justification for very important included, "The adage *too many cooks spoil the stew* come to mind."

Table 35

Round 2 Question 23 Results: Leadership Roles

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
		25%	75%	1	100%

Round 2 Question 24 asked if understanding data resources and related costs for industry best practice tools such as Flight Operations Quality Assurance, Voluntary Disclosure Reporting Programs (VDRP), and Maintenance Error Decision Aid (MEDA) prior to implementing a SMS program. Of the responses, 75% of the panelists indicated understanding data resources and related costs for industry best practice tools were either critical or very important and 25% believed they were somewhat important (see Table 36). Panelist justification for somewhat important posited it "depends on the scale and size of organization" and "many organizations need or want SMS that do not participate in these industry standard programs."

Table 36

Round 2 Question 24 Results: Data Sources and Related Costs

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
	25%	50%	25%	3	75%

Round 2 Question 25 asked panelists opinion of project planning schedule. Of the responses, 75% of the panelists believed the project planning schedule was critical or very important and 25% believed it was somewhat important (see Table 37). Typical justification comments for very important included, "This is probably the single biggest cost control item" or "cost control tool," the schedule is where one compares estimates or predictions of the project planning process with actual results in the light of the Big Three: Cost, Schedule and Performance," and the "schedule gives accountability to the program once it has been formally adopted."

Table 37

Round 2 Question 25 Results: Project Planning Schedule

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
	25%	50%	25%	4	75%

Round 2 Question 26 asked panelists their opinions of understanding employee resource costs prior to implementing a SMS program. Of the responses, 25% were critical, 50% very important and 25% somewhat important (see Table 38). Panelists' justification for critical included, "not only the upfront costs, but continuing, post implementation expenses." Justification for somewhat important included, "balanced by the concept *safety* and best practices could actually save money."

Table 38

Round 2 Question 26 Results: Employee Resource Costs

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
	25%	50%	25%	2	75%

Round 2 Question 27 asked panelists their opinions of standards for SMS training. Of the responses, 75% of the panelists indicated standards for SMS training were critical, whereas 25% indicated they were very important (see Table 39). Panelist justification for critical posited SMS training was "crucial to SMS and overall safety." Panelists' justification for very important was SMS training should be "mandatory, structured, and consistent in content."

Table 39

Round 2 Question 27 Results: Standards for SMS Training

Not important	Somewhat important	Very important	Critical	No. Comments	Agreement
		25%	75%	3	100%

Round 2 included six additional open-ended questions. The justification for adding new elements was twofold: (a) to collect expert opinion on why are the benefits of safety programs are difficult to analyze and what barriers prevent providing a business case for safety programs for decision makers and (b) to understand the relationship of variables for SMS training and program costs decision makers would expect for SMS cost estimation modeling. Question 28 was related to benefits and barriers for providing a business case for SMS programs. Questions 29 through 33 were two-part questions related to employee resources, specifically SMS training. Panelists provided their opinions of what minimum standards for each phase of an SMS Implementation Plan, in the context of labor hours, was appropriate for SMS cost estimation modeling.

Round 2 Question 28 was a two-part open-ended question that asked the panelists their opinion on why the benefits of safety programs have been difficult to analyze and what are the barriers to provide a business case for safety programs for decision makers. Training and education emerged as a means to overcome barriers. Of particular interest was the need to model costs of incidents and accidents and the predicted impact of the survival of a company. Panelists posited "when modeling accident/incident data a company may use the SWOT technique."

Round 2, Questions 29 through 33 elicited expert opinion on SMS training to develop a decision support system for SMS cost estimation. The instructions for Round 2 requested panelists to answer the questions assuming an organization had not implemented a SMS program. A brief discussion of the responses for each question follows.

Round 2 Question 29 asked the Delphi panelists their opinions of the minimum training (hours) that employees would be expected to receive for *Indoctrination/initial on SMS, human factors and organizations* during Phase 1 and their opinion of how this standard would affect program costs. Responses for the duration of training ranged between 2 and 32 hours. In general, 75% of the panelists indicated there would be a financial impact to an organization and 25% believed there would be no cost, or a minimal financial impact to an organization depending on the size of the program. Of the responses, 25% of the panelists posited all training would be a fixed cost and could be incorporated into existing training times.

Round 2 Question 30 asked panelists their opinion on what minimum standard (hours) and cost impact of *Initial (general safety) training* should an employee should receive during Phase 1. Responses for duration of training ranged between 0 and 8 hours. Of the panelists, 100% indicated there would be no cost, or a minimal financial impact to an organization. Panelists indicated training would be included as part of Phase 1, *Indoctrination/initial on SMS, human factors and organizations.* One panelist indicated there would be no impact to costs because "general safety should be a part of the company's baseline safety program." One panelist responded,

> This needs to be qualified as there are several places SMS employees my [*sic*] go/visit in the course of their duties: hangars; manufacturing facilities; POL [i.e., fuel or oxygen containment areas] facilities; welding/sheet metal/paint shops, etc.

Could be 10-15 min or 3-4 hours depending. I would plan on 4 hours for each new environment.

Round 2 Question 31 asked panelists their opinion of what minimum standard (hours) and cost impact for *Training on SMS/risk management on reactive processes* an employee should receive during Phase 2 and how this would affect program costs. Responses for duration of training ranged between 2 and 32 hours. Of the responses, 50% of the panelists indicated there would be a financial impact; however, 25% indicated there would be a minimal financial impact to an organization depending on the size of the program.

Round 2 Question 32 asked panelists their opinion of minimum standard (hours) and cost impact for *Training on SMS/system risk management on proactive and predictive processes* for Phase 3 and how this standard would affect program costs. Responses for duration of training ranged between 0 and 32 hours. Of the responses, 50% indicated there would be a financial impact to an organization and 25% indicated there would be no cost, or a minimal financial impact. One panelist responded, "Training would not be needed unless the employee is a manager or an analyst, then 16 hours would be appropriate."

Round 2 Question 33 asked for panelists' opinions on what minimum standard (hours) and cost impact for training relevant to operational safety assurance an employee should receive during Phase 4, *Operational safety assurance* and how this standard would affect program costs. Responses for duration of training ranged between 2 and 80 hours. Of the responses, 75% of the panelists indicated there would be a financial impact to an organization. Of the panelists, 25% indicated there would be no cost or a minimal financial impact and 25% indicated the training should be recurrent every year.

The responses related to SMS training from both Rounds 1 and 2 influenced the development of a tool titled Estimated Cost of Training per Hour (see Appendix Q) that could be included in a decision support system. The tool was created using Microsoft Excel and included data ranging from 10 to 30,000 employees that organizational leaders could employ. The discussions of training, size, and scope of aviation organizations in the FAA NPRM (2010d) influenced the range of the number employees. In the NPRM (2010d), FAA representative noted how leaders of an organization who may seek to comply with training are dependent on the size and scope of the organization and further defined aviation organizations as small, medium, and large aviation entities diverse in complexity related to aircraft fleet size and number of employees. An examination of the ICAO SMS model revealed total of 90 days (720 labor hours) for training was included in the model. According to the NRPM (FAA, 2010d), of the 90 air carriers in the United States, 71% were considered small entities with less than 1,500 employees and consisted of an organization with a fleet of aircraft fewer than nine. A medium aviation organization consisted of an organization with a fleet of aircraft between 10 and 49 aircraft but had less than 1,500 employees. The estimated cost of training for the five training sessions identified in the ICAO SMS model for Phases 1 through 4 was examined for organizations that could employee between 10 and 30,000 employees. The duration of training ranged from one to 80 hours, influenced by panelist's responses to Round 2 Questions 29 through 33. Here the duration of training was multiplied by the estimated number of employees in an organization using a cost of $48 per labor hour to understand the estimated cost for the training. A cost of $48 per labor hour was influenced by the wage per labor hour cost used in the NPRM (FAA, 2010d) for the Implementation Plan, specifically, the *SMS Documentation (Initial Hourly Burden)* and the *Estimated Implementation Costs*. The Estimated Cost of Training per Hour tool that could be used in a decision support system is presented in Appendix Q and includes graphical representation of the data.

The last question in the Round 2 survey instrument was an open-ended question to allow panelists the opportunity to suggest new questions or modifications to existing questions. There were seven comments to Round 2 Question 34. Only one question was considered for modification before moving to Round 3.

Round 3 (stability). Round 3 of the Delphi study took place between January 31, 2013, and February 4, 2013. At the beginning of Round 3, each panelist received feedback from Round 2, the Round 3 Questionnaire (see Appendix R), and the modeling tool titled *Estimated Cost of Training per Hour* (see Appendix Q) to stimulate further discussion. Round 3 involved exploring the reasons for the differences discovered in Round 2 of the study. Panelists reviewed the feedback from Round 2 before responding to each question provided in Round 3. Responses in Round 2 judged to be at least 75% agreement within one unit and supported by the justification or that panelists considered unimportant were not included in the Round 3 survey instrument. The Round 3 survey instrument was created from the responses to Round 2 and consisted of 14 questions. Simple ranking and Likert-type rating scales were used to explore the reasons for the differences discovered in Round 2 of the study. The first question employed a ranking-type scale following Delbecq et al. (1975). The remaining 13 questions employed a common 5-point Likert-type scale, with choices ranging from: (a) strongly agree, (b) agree, (c) neither agree nor disagree, (d) disagree, or (e) strongly disagree, with the statements posed that closely represented their opinion.

Three of the panelists responded prior to the target date for completion, which helped expedite data analysis. Communication with the last panelist revealed personal commitments would require an additional 2 weeks before the panelist could return the survey. The decision to proceed without the responses from the last panelist was made based on time constraints. It is typical in Delphi studies for panelists to not complete all rounds of the study (Grisham; 2009; Keeney, 2011). According to Delbecq et al. (1975), it would be unrealistic to expect participation unless the panelists (a) have a deep interest in the problem, (b) have motivation and interest in the outcome, (c) have important knowledge or information to share, and (d) include the Delphi tasks in their schedule.

Responses to the Round 3 survey instrument were analyzed to begin the stability process. Panelists were asked to rate their agreement to statements built on the responses of statements from the Round 2 instrument. Round 3 involved identifying areas of agreement and disagreement, with 29 justification responses provided by the panelists. The results of each question are discussed.

Round 3 Question 1 asked panelists to rank the importance of items for the development of a decision support system for SMS cost estimation, with 1 representing being the most important, 2 being the next important, and so forth. The question provided an option that included *other* to allow panelists to add additional items, which resulted in the addition of training and demonstrate implementation. Table 40 contains the results of Question 1.

Table 40

Round 3 Question 1 Results: Ranking of Factors for SMS Decision Support System

Rank	Key factors	Individual votes	Total
1	Regulations	1-1-2	4
2	Scope of work (inclusion of FOQA, VDRP, MEDA, etc.)	1-2-4	7
3	Size of an organization (number of employees requiring training)	2-3-5	10
4	Work breakdown structure (identification of work scope)	3-4-5	12
5	Financial schedules (employee wages identified in collective bargaining agreements, Bureau of Labor Statistics, company pay schedules, etc.)	3-4-8	15
6	Cost analysis	6-7-7	20
7	Cost-benefit analysis	6-7-8	21
8	Demonstrate implementation	5-9-9	23
9	Training	6-9-9	24

Note: N=3; FOQA = flight operations quality assurance; VDRP = voluntary disclosure reporting program; MEDA = maintenance error decision aid.

Round 3 Question 2 asked panelists their opinions on a statement related to the importance of regulatory requirements in assessing the scope of an SMS program. All of the panelists either strongly agreed (66.7%) or agreed (33.3%) with the importance of regulatory requirements (see Table 41). This correlates with the results of Question 1, where the panelists ranked regulations as the most important factor for the development of a decision support system for SMS cost estimation. Justifications for agreement indicated regulatory requirements provide the baseline for SMS programs that provide the minimum scope in order to develop a program. Regulatory requirements would be necessary to require enforcement, data collection, and reporting.

Table 41

Round 3 Question 2 Results: Regulatory Requirements

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
66.7%	33.3%				3	100%

Round 3 Question 3 asked panelists their opinions on a statement asking if a cost analysis should be conducted prior to implementing a safety program in order to understand expenses and demonstrate benefits. Of the responses, 100% of the panelists either strongly agreed or agreed with the statement, which did not necessarily correlate with the results of Round 3 Question 1, where the panelists ranked cost analysis as the sixth factor, out of a possible nine, for the development of a decision support system for SMS cost estimation (see Table 42). Justifications for agreement indicated it was "doubtful that one can really demonstrate the benefits in the real, live world" and a cost analysis should be accomplished as an "implementation determinate but caution as to not impede making critical safety decisions."

Table 42

Round 3 Question 3 Results: Cost Analysis

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
66.7%	33.3%				2	100%

Panelists were asked their opinions on a statement related to the significance of the WBS, specifically if the WBS provides the scope of work necessary to accomplish cost and schedule estimations. Of the responses, 66.7% were in agreement with the statement, while 33.3 % neither agreed nor disagreed (see Table 43). This correlated with the results of Round 3 Question 1, where the panelists ranked the WBS fourth, out of a possible nine factors, for the development of a decision support system for SMS cost estimation. Justification for agreement included "if the WBS is broken down to at least 1 day increments (8 hours) of scheduling then you can compute costs more precisely."

Table 43

Round 3 Question 4 Results: Work Breakdown Structure

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
33.3%	33.3%	33.3%			2	66.7%

Round 3 Question 5 asked panelists their opinions on a statement related to the significance of conducting a cost-benefit analysis prior to implementing a safety program to understand expenses and demonstrate benefits. One hundred percent of the panelists either strongly agreed or agreed with the statement, which did not correlate with the results of Round 3 Question 1, where the panelists ranked cost-benefit analysis seventh out of a possible nine factors for the development of a decision support system for SMS cost estimation (see Table 44). Panelists posited the cost-benefit analysis is a "quantitative and qualitative assessment of what the SMS HOPES to accomplish" and "as long as one considers the safety issues first as the predominate factor."

Table 44

Round 3 Question 5 Results: Cost Benefit Analysis

Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	No. comments	Agreement
33.3%	66.7%				2	100%

Round 3, Questions 6 through 9 were posed to panelists based on responses in Round 2 Question 28 that asked, Why are the benefits of safety programs difficult to analyze and what are the barriers to provide a business case for safety programs for decision makers? Table 45 contains a summary of the results of Questions 6 through 9. Question 6 asked panelists their opinions on a statement of cost benefits of safety programs are difficult to analyze because it is a different way of doing business. Of the responses, 33.3% strongly agreed with the statement, whereas 66.7% neither agreed nor disagreed. Of the responses, 100% of the panelists strongly agreed or agreed with the statement related to the cost benefits of safety programs are difficult to analyze because benefits are subjective (Question 7). Of the responses, 100% of the panelists strongly agreed or agreed with the statement related to overcoming barriers for making a business case for SMS programs companies need to understand or try to model the costs of incidents and accidents (Question 8). Panelists posited "when modeling accident/incident data a company may use the SWOT technique to help make a business case" and the cost-benefit analysis should include a worst case crash involving the aircraft at maximum "passenger load to include collateral damage at the crash site." Question 9 asked panelists their opinions on a statement related to overcoming barriers for making a business case for SMS programs, as organizational leaders need to understand the costs of undesired events and the predicted impact to the survival of the company. Of the responses, 100% either strongly agreed or agreed with the statement.

Table 45

Round 3 Questions 6 Through 9 Results: Summary Barriers to Business Case for Safety

Barrier	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Agreement
R3Q6: Different way of business	33.3%		66.7%			33.3%
R3Q7: Cost benefits subjective	33.3%	66.7%				100%
R3Q8: Modeling costs of accidents and incidents	66.7%	33.3%				100%
R3Q9: Undesired events and impact to companies	66.7%	33.3%				100%

Round 3, Questions 10 through 14 asked panelists their opinions on how the training standards the decision maker selects for Phases 1 through 4 described in the ICAO SMS model would affect program costs. Of the responses for Question 10, which asked panelists their opinions if the training standards a decision maker selects for Phase 1, specifically for *indoctrination/initial on SMS, human factors and organizations,* would affect program costs, 33.3% strongly agreed with the statement and 66.7% agreed (Question 10). Panelists were 100% in agreement with the remaining training standards a decision maker selects for Phase 1, *Initial (general safety) training* (Question 11); Phase 2, *SMS/risk management on reactive processes* (Question 12); Phase 3, *SMS/system risk management on proactive and predictive processes* (Question 13); and Phase 4, *training relevant to operational safety assurance* (Question 14) would affect program costs. Table 46 contains a summary of the results of Questions 10 through 14.

Table 46

Round 3 Questions 10 Through 14 Results: Summary SMS Training Effect on Cost

Type of training	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Agreement
R3Q10: Phase 1- Indoctrination/initial on SMS, human factors and organizations	33.3%	66.7%				100%
R3Q11: Phase 1- Initial (general safety) training		100%				100%
R3Q12: Phase 2, SMS/risk management on reactive processes		100%				100%
R3Q13: Phase 3, SMS/system risk management on proactive and predictive processes		100%				100%
R3Q14: Phase 4, Operational safety assurance		100%				100%

Summary Rounds 1 through 3. The results of all three rounds were summarized for cross-analysis. In Round 1, panelists identified 16 tools to assist in developing a decision support system for SMS cost estimation (see Table 7). As part of the study design, a SMS Cost Estimation Tool (see Appendix O) was developed after Round 1 to stimulate further discussion for Round 2. In Round 2, the panelists rated the results of each of the responses to the Round 1 survey and provided 151 justifications or clarification comments for 34 questions. Tables 47 and 48 provide summaries of the results for Round 2 and 3 for tools identified by the panelists for cross-analysis. Table 47 provided a summary of findings for tools for SMS cost estimation for Round 2, Questions 1 through 16. Table 48 provides a summary of the results for tools for SMS cost estimation for Round 3, Questions 2 through 5.

Table 47

Round 2: Summary of Questions 1 Through 16, Tools for SMS Cost Estimation

Round 2 Question	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Agreement
R2Q1: Work breakdown structure	50%		50%			50%
R2Q2: Regulatory requirements		25%	25%		25%	25%
R2Q3: Size of operation	**25%**	**75%**				**100%**
R2Q4: Cost analysis		50%		25%		50%
R2Q5: Cost-benefit analysis		50%	25%	25%		50%
R2Q6: Microsoft Excel		50%	50%			50%
R2Q7: Microsoft Project	25%	25%	50%			50%
R2Q8: Self-developed programs		50%	50%			50%
R2Q9: PERT and sharing industry best practices		**75%**		**25%**		**75%**
R2Q10: Calendar as a tool for project planning		**75%**	**25%**			**75%**
R2Q11: Experts and company knowledge	**50%**	**25%**	**25%**			**75%**
R2Q12: FAA SMS material	**25%**	**50%**		**25%**		**75%**
R2Q13: Internal programs	**25%**	**50%**	**25%**			**75%**
R2Q14: Metrics		**75%**	**25%**			**75%**
R2Q15: Similar complex projects		**75%**		**25%**		**75%**
R2Q16: SMS training tool	**25%**	**50%**	**25%**			**75%**

Note. Items reaching agreement are identified in boldface font.

Table 48

Round 3: Summary of Questions 2 Through 5, Tools for SMS Cost Estimation

Round 3 Question	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Agreement
R3Q2: Regulatory requirements	66.7%	33.3%				100%
R3Q3: Cost analysis	66.7%	33.3%				100%
R3Q4: Work breakdown structure	33.3%	33.3%	33.3%			66.7%
R3Q5: Cost-benefit analysis	33.3%	66.7%				100%

Panelists were asked to identify information sources for data related to labor and schedule standards. Table 49 provides a summary of the results for Round 2, Questions 17 through 22 concerning labor and schedule standards.

Table 49

Round 2: Summary of Results Round 2 Questions 17 Through 22, Labor and Schedule Standards

Round 2 Question	Not important	Somewhat important	Very important	Critical	Agreement
R2Q17: Collective bargaining agreements	**25%**	**75%**			**75%**
R2Q18: Company standards		**50%**	**50%**		**100%**
R2Q19: U.S. BLS financial schedules	**75%**		**25%**		**75%**
R2Q20: Safety officer labor hours	**25%**	**75%**			**75%**
R2Q21: Public labor laws	50%	50%			50%
R2Q22: Title 14 Part 121.471 as source of data		**75%**	**25%**		**100%**

Note. Items reaching agreement are identified in boldface font.

Round 1 seed Question 4 asked panelists to identify any additional information a decision maker would be interested in prior to implementing a SMS program. Table 50 summarizes the results of Round 2, Questions 23 through 27 related to knowledge of interest to decision makers prior to implementing a SMS program.

Table 50

Round 2: Summary of Results Round 2 Questions 23 Through 27, Knowledge of Interest to Decision Makers

Round 2 Question	Not important	Somewhat important	Very important	Critical	Agreement
R2Q23: Leaderships roles			25%	75%	100%
R2Q24: Data sources and related costs		25%	50%	25%	75%
R2Q25: Project planning schedule		25%	50%	25%	75%
R2Q26: Employee resource costs		25%	50%	25%	75%
R2Q27: Standards for SMS training			25%	75%	100%

An additional question posed in Round 2 (Question 28) regarding panelists' opinions on why the benefits of safety programs have been difficult to analyze and what are the barriers to provide a business case for safety programs for decision makers. The results of panelists' responses were reported in Table 45. The results of Round 2, Questions 29 through 33 related to expert opinion on SMS training to develop a decision support system for SMS cost estimation was reported in Table 46. The responses related to SMS training from both Rounds 1 and 2 influenced the development of a tool titled Estimated Cost of Training per Hour (see Appendix Q) which was previously discussed. Finally, panelists ranked the importance of items for the development of a decision support system for SMS cost estimation (see Table 40).

Evaluation of Findings

The opinions of a purposefully sample of aviation management experts in project management and cost analysis for project planning were queried across three rounds of structured inquiry procedures. The modified Delphi method was used as the research methodology, which allowed for soliciting expert opinion when accurate information was unavailable (Hasson & Keeney, 2011; Linstone & Turoff, 2011) and aimed to explore group attitudes and opinions (Hasson & Keeney, 2011). The data collected focused on two research questions which were examined in light of two theories: (a) theory of quality management and (b) ABC principles. Data were compared and contrasted to previous research which is presented below and compared for the contextual impact on the field of aviation.

Question 1: Key factors in a decision support system. The expert panelists identified nine key factors for the development of a decision support system for SMS cost estimation presented in Table 40. The top six key factors were (a) regulations, (b) scope of work, (c) size of an organization, (d) WBS, (e) financial schedules, and (f) cost analysis. Each key factor for the development of a decision support system for SMS cost estimation is briefly discussed.

Regulations. Regulations were considered important for the development of a decision support system for SMS cost estimation because they provide the minimum foundation of elements which are defined by governing authorities. Hsu et al. (2010) and Liou et al. (2008) published recent studies where aviation experts accessed key elements of SMS. The findings of the current study were somewhat consistent with Liou et al.'s, (2008) study in which a fuzzy DEMATEL method was used to survey 20 aviation experts to assess the impact of 11 factors identified by regulatory authorities and managers in the Taiwanese airline industry. Liou et al. found documentation the second most important factor that influenced an effective SMS, which included functions such as regulatory requirements and standard operating procedures. In contrast, an empirical study (Hsu et al., 2010) that included grouped key components of SMS using guidance data from ICAO and four aviation authorities worldwide, regulations were weighted 11th out of 25 components. Although Hsu et al. developed a quantitative evaluation model that identified key components of SMS, the model did not include key project constraints such as financial cost. Financial costs to organizations were not a component in Hsu et al.'s study because ICAO and the four aviation authorities provided the guidance data used in the study.

The panelists considered moving beyond regulation compliance important, which was consistent with much of the aviation SMS literature (Čokorilo, 2011; Hsu et al., 2010; Lercel et al., 2010; Lu, Schreckengast, et al., 2011). The adequacy of regulatory requirements was somewhat consistent with the findings of Layton (2012) and Mokaya

(2009). Mokaya reported the role of regulation and clear policy guidelines resulted in inadequate SMS in the aviation industry in Kenya. Layton (2012) examined international accident rates with different governing agencies regulatory oversight and found existing regulations were not adequate for global safety oversight. In the context of policy, panelists noted regulations were "minimum standards and not necessarily best industry practices" and noted advisory circulars "give better scope." However, the panelists provided no specific advisory circulars for discussion. In a study that involved examining 872 safety recommendations by the NTSB from accidents involving Part 121 and 135 operators, approximately two-thirds of the areas of improvement included administration and organizational themes such as information management and communication, specifically disseminating information to include advisory circulars and the improvement of data collection and storage (Shappell & Wiegmann, 2009).

Scope of work, size of organization, and work breakdown structure. The first theme that emerged from analysis was the size and scale of an organization. Three factors were found to have similar themes: (a) WBS, (b) scope of work, and (c) size of an organization. Liou et al. (2008) similarly grouped the causal relationships of 11 factors to create an impact-relations map to visualize a generic SMS structural model. The panelists ranked the size of an organization third in importance for the development of a decision support system for SMS cost estimation. Panelists considered the size of an organization important in understanding data resources and related costs for industry best practice was consistent with project management literature (Doloi, 2011; Jørgensen et al., 2012), SMS literature (Cox & Flouris, 2011; Flouris & Kucukyilmaz, 2009; Liou et al., 2008; Lu, Schreckengast, et al., 2011), and SMS guidance material (FAA, 2010d; ICAO, 2009). Cox and Flouris examined the benefits of SMS from a micro-analysis perspective for ROI of SMS program initiatives, however, their study did not include initial financial costs of SMS implementation to obtain a true value of ROI. Jørgensen et al. (2012) examined the effect of project size on cost estimation bias in the context of engineering projects and questioned the robustness of many studies reporting the percentage of cost overrun.

Panelists ranked scope of work second in importance for the development of a decision support system for SMS cost estimation, specifically for the inclusion of FOQA, VDRP, and MEDA. Panelists agreed tools such as flight assessment, hazard reporting systems, and internal evaluation programs were important in a decision support system for SMS cost estimation; however, justification for agreement included they would assess the predicted scope of the programs to ascertain costs of the entire program but "not as standalone decision support mechanisms." In the current study, panelists' responses were consistent with cost estimation (Doloi, 2011; Trivailo et al., 2012) and project management literature (Choi & Kwak, 2012; Karapetrovic & Casadesús, 2009). In a prior study (Karapetrovic & Casadesús, 2009) that involved surveying 176 organizations were surveyed to understand when management standards were implemented by organizations to provide confidence to different stakeholders, the scope of work was important when sequential of management systems were implemented within an organization, such as ISO 9001, which was found to avoid duplication of effort, simplified work procedures, and improved communications between workers. The importance of scope of work was emphasized in a study (Karapetrovic & Casadesús) where the scope of work for subsequent management systems were found important after implementation of three common standards: (a) ISO 9001 (quality), (b) ISO 14001 (environmental), and (c) OSHAS 18001 (occupation safety). In the current study, panelists posited "some safety programs are very tangible in terms of benefits i.e. FOQA and Flight Data Monitoring (FDA)" but difficult "to quantify and qualify in terms of higher/better levels of safety." The findings were consistent with prior research (Lowe et al., 2012) that focused on the usefulness of FOQA, but not program costs who posited the benefits or concerned about risks may depend on demonstrating benefits with minimal costs to the operator. Lowe et al. reported it was difficult to justify the cost of implementing and maintaining a FOQA program, possibly influenced by pilot perceptions of the program.

Panelists ranked WBS fourth in importance for the development of a decision support system for SMS cost estimation, which was consistent with project management literature (Doloi, 2011; Eldin & Hamza, 2009; Guillerm et al., 2012; Phillips et al., 2012; Trivailo et al., 2012). A detailed WBS was necessary for the planning stage of projects to reduce extra work and resources used for the project, which equates to reduced costs and time (Phillips et al., 2012). Trivailo et al. (2012) examined cost estimation models, methods, and tools in the aerospace sector, many were found to build on the foundation of WBS or cost breakdown structure (CBS). Trivailo et al. highlight the parametric-based approach, based on historical data, as the most frequent cost estimation model typically used in acquisition processes and was unlikely to yield accurate estimates due to insufficient historical data. Qian and Ben-Arieh (2008) presented a cost estimation model that linked parametric and ABC methods useful in early designs of product manufacturing. Safety engineering approaches included the development of WBSs to provide information for management decision making (Guillerm et al., 2012).

Financial schedules. The fifth key factor for the development of a decision support system for SMS cost estimation was financial schedules. Specific examples of information sources included the financial schedules provided by company standards, collective bargaining agreements, and data sources readily available to the public, such as the financial schedules provided by the BLS. Cantor (2008) reported collective bargaining agreements between organizations and labor unions were typical sources of data for cost estimation activities. In a justification comment, a panelist indicated "it would depend on how CBA would impact the cost estimation activities." According to Laroche and Wechtler (2009), a well-known effect of labor unions was higher labor costs. In contrast, Greer (2009) found the impact of unions was statistically insignificant in terms of airline efficiency. Cantor noted many labor unions influenced decisions with Congress and regulatory agencies. A review of data sources for collective bargaining agreements found the U.S. Office of Personnel Management Labor Agreement Information Retrieval System (LAIRS) database was a source of information on labor-management relations in the U.S. federal government (U.S. Office of Personnel Management, 2012).

Although panelists rated financial schedules fifth in importance for SMS cost estimations, 75% of the panelists noted BLS financial schedules were not an important source of data. In a study that reviewed safety literature (Swuste et al., 2010) has produced much of the safety metaphors in the safety domain in lieu of safety theories, the BLS was reported to provide important safety measures for benchmarking risk measures. In contrast, financial schedule data provided by the BLS were found useful in a study

(Wang et al., 2013) which examined the impact of financial condition of airlines and safety investments. Of the findings of this study, first-line specialists (25%) posited the BLS financial schedules were a very important source of data for SMS cost estimations and posited they were useful for ROM estimates consistent with the literature (Jallon et al., 2011; Kniesner et al., 2010). Colley and Neal (2012) reported similar findings of disagreements between management, supervisors, and workers, in the context of a safety culture. Colley and Neal found upper management was concerned with people, supervisors were concerned with management practices, and workers were concerned with procedures. The literature review included information and data sources for project cost estimations, such as the BLS. Researchers have used BLS financial schedules to study the impact of financial conditions on airlines and safety investments (Wang et al., 2013; Jallon et al., 2011; Kniesner et al., 2010).

Cost analysis. Cost analysis was the sixth key factor identified by the panelists as a decision making tool for SMS cost estimation. Panelists posited cost analysis was information a decision maker would be interested in prior to SMS program implementation, specifically initial financial costs, which was consistent with project management literature (Briciu & Capusneanu, 2010; Trivailo et al., 2012). In a study (Briciu & Capusneanu, 2010) related to tools used in ABC methods, cost importance was found significant for contributions to monitoring and measuring performance, specifically, with other tools such as dashboards and balanced scorecards which emphasize different perspectives of finance, internal business, customers, learning and growth. As previously mentioned, panelist posited cost analysis were particularly useful for ROM estimates. The use of ROM was found to be a generally acceptable approach in the literature for project cost estimations for early planning phases when requirements have not been explicitly specified (Trivailo et al., 2012). The value of cost analysis as a tool for decision makers has been recently studied in domains such as manufacturing (Abdullah & Tari, 2012) in terms of QMS certification; in academics (Woolston, 2012) in terms of university accreditation, and in the food industry (Chryssochoidis et al., 2009) in terms of investments of traceability systems. In contrast, the value of cost analysis as a tool for decision makers prior to investments was questionable. The fact that one panelist noted "recognizing this is an academic exercise to justify time commitments and costs, the scope of the research process cannot be conducted in an isolated or pristine environment" was somewhat consistent with the ongoing debate in the literature on cost information for regulatory decision-making (Harrington et al., 2009).

Questions were posed to panelists to understand why the benefits of safety programs were difficult to analyze and what barriers make it difficult to make a business case for safety programs for decision makers. All of the panelists agreed cost benefits of safety programs are difficult to analyze because benefits are subjective. The findings were somewhat consistent with Thomas (2012), who examined the effectiveness of SMS across multiple industries and reported that researchers in many quantitative studies have only "measured subjective perceptions of safety rather than objective measures" (p. iii).

Of particular interest were panelists' opinions of the need to understand or model the costs of incidents and accidents to overcome barriers for making a business case for SMS programs. Liou et al. (2008) which identified 11 factors for a generic SMS structural model, and a panel of aviation experts identified event and remedy costs as a factor of incident investigation and analysis. Event and remedy cost was considered a risk assessment tool in relation to the cost of an accident or incident and the cost of corrective actions to prevent future reoccurrence in much of the SMS literature (Lercel et al., 2011; Michell & Braithwaite; 2009; Čokorilo et al., 2010). In a study that examined financial risk in the context of aircraft accidents (Čokorilo et al., 2010), the authors posited cost assessments were dependent on aircraft age and accident severity. Michell and Braithwaite (2009) researched cost analysis methods to aid decision-makers who seek to mitigate future costs and assess the value of proposed safety initiatives in the context of aircraft accidents.

Panelists posited the SWOT technique could be used when modeling accident and incident data. Project management and quality literature (Benta, Podean, & Mircean, 2011; Hagos & Pal, 2010; Pryor, Toombs, Anderson, & White, 2010) explained the SWOT technique is an analysis model used to understand a firm's strengths, weaknesses, opportunities, and threats. The findings of this study were somewhat consistent Huang et al. (2009), who examined financial decision makers' perceptions on safety investments reporting the need to understand an organization's financial losses so that managers could understand the financial benefits of safety investments. Huang focused on medium to large companies employing more than 100 employees to access financial decision makers' perspectives towards safety, health, and environmental (SH&E) issues.

Panelists posited training was a means to overcome barriers. The findings corresponded with a study on aviation SMS implementation by Mokaya et al. (2009), who identified major barriers to SMS implementation in Kenya and found safety training was a major factor. Veltri and Ramsay (2009) developed an economic analysis model, and the initial financial assessment served as a baseline for program evaluation prior to implementing of training and educational programs to overcome barriers for safety, health, and environmental programs. After conducting 74 audits of aviation operators in 2011, the Professional Resources in System Management (PRISM, 2011), an aviation services company, reported SMS training was the second highest SMS management problem area.

Question 2: SMS project cost model. Research Question 2 asked how to model SMS cost estimates existing information sources to provide decision makers with a framework for SMS program strategies. Understanding total costs prior to SMS program implementation enables decision makers to make informed decisions on resources needed for successful implementation. In the current study, panelists identified tools, labor standards, schedule standards, and information decision makers would be interested in prior to SMS implementation.

A review of the seed questions in Round 1 and the results of successive questions posed to panelists in Rounds 2 and 3 indicated that agreement was reached among the panelists for the tools necessary to develop a decision support system for SMS cost estimation. Agreement was reached in Round 2 for 56.3% of the tools identified in Round 1. Responses in Round 2 judged to be at least 75% agreement within one unit or that panelists considered unimportant for this study supported by the justification were not included in the Round 3 survey instrument. In Round 3, panelists reached agreement for tools necessary to develop a decision support system for SMS cost estimation. Agreement was reached for all information sources for data related to labor and schedule standards, with the exception of public labor laws. Agreement was reached for barriers, with the exception of different way of business.

Based on the literature and findings of the current study, a high-level framework was developed for SMS cost estimation modeling. The high-level framework included:

- Key factors for a decision support system framework.
- Knowledge of scope of work. The initial drivers for this study were provided in the ICAO SMS model (ICAO, 2009), specifically the Gantt Chart- SMS Implementation Plan. The SMS Cost Estimation Tool (see Appendix O) provided the baseline scope of work identified in the ICAO SMS model (ICAO, 2009) WBS, adjusted for labor cost.
- Knowledge of tools that could be used in cost estimation methods, such as WBS, IT, training standards, and financial schedules.
- Knowledge of data sources that could be used in cost estimation methods, such as financial schedules.
- Knowledge of size of organization to understand resources.
- Knowledge of training standards of stakeholders. The Delphi panelists' perceptions of training standards varied between 0 and 80 hours, posited by some to only include "managers and analysts." An Estimated Cost of Training per Hour Tool (see Appendix Q) that could be referred to by decision makers and analysts for ROM training estimates was developed in this study. The ROM training estimates could then be adjusted for variables and cost drivers after a gap analysis definitively identified scope of work for specific organizations.

Cost estimation tools. The panelists identified 16 tools that could be used to assist in the development of a decision support system for SMS cost estimation, which were presented in Table 7, and have already been discussed. The tools were categorized into nine common themes reported in Table 8. Of particular interest was SMS training perceived by the panelists as a tool to overcome barriers and the perceived impact to program cost. Panelists viewed SMS training in two different contexts: (a) as a tool to educate personnel on the value of SMS programs and (b) to analyze the resources necessary to perform program cost estimation. SMS training was one of many critical success factors in Hsu et al.'s (2010) study on the key components of SMS using guidance data from ICAO and four aviation authorities worldwide. Safety training was reported as a significant component in much of the occupational, health, and safety literature (Hsu et al., 2012; Vinodkumar & Bhasi, 2010) and aviation SMS literature (Shappell & Wiegmann, 2009).

All panelists indicated training would affect cost estimation activities but none quantified their opinions in the context of financial cost. Of interest, was the perceived value of training between upper management, middle management, and first-line specialists. Of the panelists (75%) who reported their positions as upper management, all believed less training was necessary when compared to middle management and first-line specialists. Panelists also suggested training would only be needed for managers and analysts. Previous research which explored the relationships between safety investment, airline financial condition and accident propensity (Wang et al., 2013), found a 10% increase in airlines' safety expenditure modeled (i.e., total maintenance and training expenses) was associated with a decrease of 9.34% in its accident rate.

The ICAO SMS model requires organizational leaders to maintain records for training and allows the leaders to define the duration (time) each employee should receive related to SMS programs (ICAO, 2009). Panelist responses related to SMS training influenced the development of tools to include in a decision support system. In the NPRM (FAA, 2010d), FAA representatives noted how an organization may seek to comply with training is dependent on *size and scope* of the organization and further defined aviation organizations as small, medium, and large entities diverse in complexity related to aircraft fleet size and number of employees.

Also of interest were panelists' opinions that conducting a PERT analysis and sharing industry best practices were tools expected in a decision support system for SMS cost estimation. Of the responses, 75% of the panelists who reported their positions as upper management all indicated PERT analysis was a tool that could be used in a decision support system for SMS cost estimation, while 25% of middle management and 25% of first-line specialists posited "PERT is a scheduling tool, not a cost estimation tool and is used to crash or rush the project, which will drive costs up." Project management methods typically use PERT techniques to analyze a time-cost trade-off by the shortening of a project time by devoting more resources to activities (Chen & Tsai, 2011; Choi & Kwak, 2012; Estevez-Fernandez, 2011). Trietch and Baker (2012) reported PERT and critical path method were the first computerized project management decision support systems with a focus on creating and controlling project schedule and posited further research was necessary to include cost considerations.

Additional items suggested by the panelists were various software tools, such as Microsoft Project Manager and Microsoft Excel that would include the scope (WBS), time, and cost breakdown, many of which include features for planning, scheduling, charting, and monitoring budgets. Panelist opinions that Microsoft Excel was a tool for cost estimation models were consistent with some scholarly literature for cost estimation modeling (Eklin et al., 2009; Román, 2011; Trivailo et al., 2012) and reported as a tool in guidance literature (FAA, 2012b; ICAO, 2012) for planning activities and calculating performance indicators. Microsoft Excel was used as the primary tool that analyzed business activities or factors that were drivers of operating costs in a case study (Román, 2011) that examined the financial situation of a major airline in order to teach undergraduate and graduate students regression analysis, which is a statistical technique that uses historical data to predict costs, revenues, and so forth. In contrast, some cost estimation model literature (Ayvaz & Pehlivanli, 2011; Doloi, 2011; Duran et al., 2012; Jallon et al., 2011) did not include software tools such as Microsoft Excel. Panelists' suggestion that Microsoft Project was a good tool when PERT and Gantt charts are used for project duration estimates indicated panelists focused on project management techniques controlled by an organization's internal process management processes, which were not the focus of the current study.

FAA SMS material was another tool panelists (75%) posited could be used in a decision support system for SMS cost estimation, although the panelists did not identify specific SMS material for discussion. Panelists who provided justification comments for strongly disagreed indicated they were not aware of any FAA SMS material that had valid cost estimations and further posited that the cost estimations in the NPRM did not have a cost breakdown available for analysis. One panelist noted, "Some of the existing cost predictions would scare off event *[sic]* the most enthusiastic safety champion." The literature review included resources and guidance material related to SMS provided by the FAA, such as AC 120-92 (FAA, 2006) which was revised in 2010 by AC 120-92A (DOT, 2010). Lu, Schreckengast, et al. (2011) used the ICAO SMS model and AC 120-

92 as tools to develop a hazard management system for airports.

Labor standards. Concerning labor standards and sources, panelists noted financial schedules and regulations were sources of data for developing a decision support system for SMS cost estimation. Of particular interest was panelists' opinion that labor hours for one specific labor category (safety officer) could be a source of data for program cost estimation modeling. Of the responses, those in upper management and academics considered the labor hours of safety officers somewhat important, whereas those in middle management and first-line specialists indicated the labor hours where not important for the development of a decision support system for SMS cost estimation. Tsai and Hsu (2008) used a simplified example of ABC techniques to assess the cost of corporate social responsibility efforts, and the resources consumed where in the form of labor hours of consultants and training activities for employees. In the preliminary assessment for this study, the cost of operators (SMS managers) was identified as information decision makers would be interested in prior to implementing a SMS program. Cost estimation models might include data related to different labor categories and would be defined by an organization's internal control processes. Cost estimation involves analyzing a predetermined scope of work and then determining the resources needed to perform the work, sometimes manipulating known information and requiring the use of experience and judgment (Čokorilo et al., 2010).

Panelists posited company standards provided "realist information but only if the standards were published." According to Delbecq et al. (1975), if responses in a Delphi method study do not generate the information needed for decision-making, the researcher should modify the questions, making them either more specific or more generalized. It was anticipated the responses would provide more detailed information on company standards. However, this type of data was not critical to answer Research Question 2, but would have been useful for case studies for future research.

Panelists indicated Title 14 Code of Regulations, Part 121.471, *Flight time limitations and rest requirements: All flight crewmembers*, was a source of data that researchers could use for program cost estimation modeling. The regulation was not anticipated as a source of data for program cost estimation because it concerned the work hour limitations of flight crew members. The literature review did not provide insight into labor standards or sources of information to use to develop a decision support system for SMS cost estimation, possibly indicating process management and business concerns are not adequately addressed.

Schedule standards. Concerning schedule standards, in the context of labor hours, the first round included a seed question developed to understand schedule standards and sources of information expected to be used to develop a decision support system for SMS cost estimation. The question was influenced by the literature related to problems with program management, specifically, factors that could affect project schedules (BLS, 2011; Choi & Kwak, 2012; Stathis, 1999) and the methods for estimating (Mochal, 2006) and controlling (Vanhoucke, 2012) project schedules. Panelists identified project schedule as a tool and information decision makers would be interested in for SMS cost estimation modeling. The results were consistent with literature (Vanhoucke. 2012), where the project schedule baseline acted as the point-of-reference for the project control phases. Vanhoucke posited research has expanded project scheduling models but many practitioners apply basic scheduling principles to cope with project uncertainty. In contrast, some researchers (Barclay, 2008; Bryde, 2008), argued traditional project success criteria in terms of quality, time, and cost must include other success criteria as defined by the stakeholders. Barclay (2008) explained the triple constraint method (time, cost, and quality objectives) was limited in that it does not include links to the project's service or product.

SMS cost estimation tool development. The SMS Cost Estimation Tool (see Appendix O) was created by transferring the ICAO SMS model WBS into a Microsoft Excel format. Panelists suggested decision makers would be interested in "not only the upfront costs, but continuing, and post implementation expenses." The current study provided a theoretical answer for SMS program upfront costs that used ABC principles that transformed the ICAO SMS cost model labor hours into financial cost that was summarized in Table 12. While informative, the decision support system tool did not account for multiple labor categories for strategic planning activities or training duration variables. Although, panelists in the current study posited the safety officer labor hours were sources of data that could be used for program cost estimation modeling the finding was not consistent with the literature. The safety literature (Chen & Chen, 2012; Flouris & Kucukyilmaz, 2009) and SMS guidance material (DOT, 2010; ICAO, 2009, 2012) emphasized safety program strategies and objectives would be determined by several managers within an organization (i.e., top management, safety manager, quality assurance manager, various subject matter experts). A content analysis of the ICAO SMS model WBS found at least 48 work tasks could include additional labor hours for more than one labor category. For example, in Phase 1, one work task was identified as *develop safety objectives for the SMS*, with an expected duration of 5 days, which could include several labor categories. In addition, the content analysis revealed 5 work tasks related to training could include additional labor hours that could have a significant impact on financial costs; however, financial costs could be grossly underestimated.

Training cost estimation tool development. While the SMS Cost Estimation Tool (see Appendix O) was found to be informative, an additional tool was needed to understand financial costs for training that could be included in a decision support system for SMS cost estimation, specifically a tool for estimating cost of training per hour. The ICAO SMS model (ICAO, 2009) WBS included four distinct phases, with training identified for each phase. Panelists posited SMS training was information a decision maker would be interested in prior to SMS implementation, however, there were no known studies related to SMS training duration or associated financial costs, which was supported by the fact that one panelist noted "there is not a clear or specific discussion of industry best practices." Standards related to the amount of time (duration) each employee should receive for SMS training could be a significant financial impact to program dependent on size of organization. A tool titled Estimated Cost of Training per Hour was developed (see Appendix Q) in order to understand financial costs for training that could be included in a decision support system for SMS cost estimation. An examination of the ICAO SMS model revealed total of 90 days (720 labor hours) for training was included in the model. The 720 labor hours is equivalent to $34,560 at $48 per labor hour. In a different context, the 720 labor hours could be equivalent to one hour of training for 720 employees, 40 hours of training for 18 employees, or 80 hours of training for nine employees. In summary, with reference to the Estimated Cost of Training per Hour tool, in theory, training costs could range between $480 to as much as

$5,529,600,000 dependent on size and scope.

Additional information. Concerning information a decision maker would be interested in prior to SMS program implementation, panelists provided 28 responses categorized into 11 themes, as shown in Table 11. The themes were (a) cost analysis, (b) cost-benefit analysis, (c) data sources, (d) industry best practices, (e) leadership, (f) modeling, (g) program design, (h) regulatory requirements, (i) resources, (j) responsibilities, and (k) scope of work. The current study was somewhat similar to previous research (Liou et al., 2008) that examined organizational and management factors to develop an effective SMS in which safety factors were identified by a group of aviation experts consisting of Taiwan regulators, the Aviation Safety Council, and members of the aviation industry. Although the goal of Liou et al. (2008) was not to examine program costs, incident investigation and analysis was identified as a factor, and event and remedy cost were functions of this factor.

Theoretical contribution. The evolving theory of quality management provided the theoretical foundation in the current study to obtain knowledge to facilitate organizational learning and continuous improvement processes to stimulate further discussion and approaches of the safety and quality management methods. The meanings of the findings were interpreted, building on the foundation of two theories: (a) the theory of quality management and (b) the theory of ABC principles. The SMS programs are built on the foundation of QMS concepts, yet theory development and measurement issues continue to be weak in both safety and quality management literature (Flynn, Schroeder, & Sakakibara, 1994; Stoop & Dekker, 2012). Much of the literature related to quality management has typically focused on quality of products (Zhang et al., 2011) and, within safety management, on culture issues and reactive processes (Allen et al., 2010; Atak & Kingma, 2011; Čokorilo et al., 2011; Mearns et al., 2013), with little emphasis on theoretical development (Stoop & Dekker, 2012).

Zu et al. (2008) explained there are seven common practices in quality management: (a) top management support, (b) customer relationship, (c) supplier relationship, (d) workforce management, (e) quality information, (f) product/service design, and (g) process management. The influence of many of these practices has been empirically studied to understand the effects on firm performance using what some researchers (Abdullah & Tari, 2012; Fotopoulos & Psomas, 2009; Zu et al., 2008) described as hard quality management factors (e.g., process management, metrics) and soft quality management factors (e.g., top management commitment, planning, employee involvement, customer focus, fact-based decision making). According to Fotopoulos and Psomas (2009), both hard and soft quality management constructs are necessary for organizational improvement. Abdullah and Tari (2012) explained hard quality management practices as the "technical tools and techniques" (p. 177) and soft quality management practices as concerned with the "management of people, relationships and leadership" (p. 178). Anderson et al. (1995) developed a theory of quality management by identifying seven constructs building and building on the foundation of Deming's management methods. These constructs were (a) visionary leadership, (b) process management, (c) internal and external cooperation, (d) learning, (e) continuous improvement, (e) employee fulfillment, and (f) customer satisfaction.

Summary

The qualitative study employed a modified Delphi technique to allow for a panel of aviation industry experts to contribute a critical knowledge base to the study (Linstone & Turoff, 2011). The study design consisted of a preliminary assessment, study announcement, participation solicitation, and three Delphi rounds. Four Delphi panelists with distinct levels of expertise to represent the aviation field participated in the study after meeting selection criteria that was determined by a small group of experts in a preliminary assessment of the study. All four of the panelists completed Round 1 and 2, while only three of the four panelists completed all three rounds. Two research questions were developed to guide the study to acquire data the researcher examined to identify the key factors in the development of a decision support system for SMS cost estimation and how SMS project cost estimates could be modeled using existing information sources in the aviation business environment. The research findings were derived from the data collected from a three round modified Delphi method.

In the first round, panelists responded to five open-ended seed questions resulting in 86 responses categorized by four similar areas of interest (a) cost estimation tools, (b) labor standards and sources, (c) schedule standards, and (d) key information prior to SMS implementation. The panelists identified 16 tools that could be used for a SMS cost model, which included (a) internal reporting programs (e.g., FOQA, VDRP, MEDA), (b) cost analysis, (c) SMS training, (d) WBS, (e) PERT, (f) Microsoft Excel, (g) Microsoft Project, (h) regulatory requirements, (i) size of operation, and (j) FAA SMS material. The tools were categorized into nine common themes: (a) program design, (b) process management, (c) scope of work, (d) industry best practices, (e) IT, (f) resources, (g) modeling, (h) regulatory requirements, and (i) user implementation tools. The panelists identified labor standards and sources categorized into three themes (a) data sources, (b) regulatory requirements, and (c) process management. Schedule standards were categorized into four common themes: (a) modeling methods, (b) resources, (c) data sources, and (d) regulatory requirements. Panelists identified information a decision-maker responsible for the implementation of a SMS program in the aviation industry be interested in knowing before implementing a SMS program categorized into 11 themes (a) cost analysis, (b) cost benefit analysis, (c) data sources, (d) industry best practices, (e) leadership, (f) modeling, (g) program design, (h) regulatory requirements, (i) resources, (j) responsibilities, and (k) scope of work. A SMS Cost Estimation Tool (see Appendix O) was developed to translate work task time into labor costs elements resulting in new theoretical cost knowledge of the ICAO SMS model.

In the second round, panelists responded to 34 questions that resulted in 151 comments. Panelists' responses were judged to have reached agreement on 19 of the 27 Likert-type questions. Panelists responded to six two part open-ended questions which resulted in 58 comments. The first two part open-ended question was posed to understand expert opinion on why the benefits of safety programs are difficult to analyze and what barriers prevent providing a business case for safety programs for decision makers, resulting in 9 comments. Panelists responded to five two part open-ended questions to understand the relationship of variables for SMS training and program costs decision makers would expect for SMS cost estimation modeling which resulted in the development of an Estimated Cost of Training per Hour tool (see Appendix Q).

In the third round, the Delphi panelists identified nine key factors for developing a decision support system for SMS cost estimation that included: (a) regulations, (b) scope of work, (c) size of an organization, (d) WBS, (e) financial schedules, (f) cost analysis, (g) cost benefit analysis, (h) demonstrate implementation, and (i) training. Panelists provided responses to 13 Likert-type questions resulting in 36 justification comments. Panelist responses were judged to reach agreement with 12 of 13 questions. One question fell below the 75% agreement but was judged to be in agreement as supported by panelist justification comments.

Chapter 5: Implications, Recommendations, and Conclusions

The purpose of the current qualitative study was to identify key factors in the use of a decision support system framework for SMS program cost estimation. The study explored how to model SMS cost estimates using existing information sources to provide decision makers with a framework for SMS program strategies (Lu, Young, et al., 2011). The problem of focus for the qualitative study was that SMS programs have not always been implemented in the aviation industry, as actual program costs could not be determined comprehensively and definitively (Avers et al., 2011; Rosenkrans, 2012; Lu, Young, et al., 2011). The implementation of voluntary aviation safety programs has consequently remained stalled (Chilester, 2007; FAA, 2010c; Lowe et al., 2012). The research method used for the study was a qualitative approach using a modified Delphi technique (Bolger & Wright, 2011; Grisham, 2009; Hallowell & Gambatese, 2010).

Limitations. One significant limitation of the study was the factor of time, which was mitigated by selecting participants who had a strong interest in the topic and results of the study, as suggested in the literature (Bolger et al., 2011; Linstone & Turoff, 1975). All panelists showed a sincere interest in participating in the study and learning the results. The response rate from the aviation and professional organizations for participant recruitment was lower than expected and online professional networks may have provided a better source to recruit participants for this study.

According to van de Linde and van der Duin (2011), every participant has some underlying theoretical assumptions. Although several of the factors identified by the panelist were consistent with current project management and cost analysis literature there were some elements that where there was a lack of agreement. The lack of agreement may be indicative of the small sample size and panelist experience with decision support systems and cost analysis for project management influenced by panelists' demographic or philosophical differences. One limitation of the study was the number of potential participants who met the qualification criteria for induction to the Delphi panel. The response to the participant solicitation was less than anticipated but assumed to be the result of purposefully targeting a sample with interests in safety management, which included qualification criteria in project management and project cost analysis, which many practitioners in the safety domain might not possess. The demographic data of the panelists included multiple aviation industry sectors and types of operations; however, the level of multiple expertises was not known and may have been better determined by requesting professional certification data within the different domains. Consideration was given to excluding professional consultants from participation in the study because they have the potential to receive financial gains from companies that may implement safety programs and may have biased the results of the study. The decision to include the consultants in the study was influenced by their extensive aviation background, expertise with project management and cost analysis for project planning, and potential to contribute valuable knowledge to the study.

Ethical issues. According to Linstone and Turoff (2011), the growth of social networks has fostered a new age of participation, where younger generations want to voice their views and receive recognition for their contributions to society. As part of the study design, panelists were given the option to remain anonymous or receive recognition for participation after the study as suggested by several researchers to improve panelist recruitment and retention over Delphi rounds (Bolger & Wright, 2011; Linstone &

Turoff, 2011; Rowe & Wright, 2011; Silverman, 2010). Each participant who consented to receiving recognition for his or her contribution in the study was identified in the Acknowledgements section. A copy of the results of this study were also provided to representatives of ICAO as part of the agreement for the use of the ICAO SMS guidance material.

Chapter 5 contains three sections. The first section includes a discussion on the implications of the study. The second section contains recommendations for practical applications of the study and recommendations for future research. The conclusion of the study contains a summary of the key points of the chapter.

Implications

The findings of this study led to conclusions that resulted in identifying several implications for a decision support system for SMS cost estimation in the aviation sector. The perspectives of a group of professionals with expertise in project planning and cost analysis were sought through a Delphi method to identify key factors, business applications, labor standards and sources, schedule standards, and other information to be found in a decision support system framework for SMS cost estimation. The implications of this study are discussed in the context of the two research questions that guided the study.

Research Question 1. What did experts in the aviation industry perceive were the key factors in the development of a decision support system for SMS cost estimation? Data were collected to identify key factors in the use of a decision support system framework for SMS program cost estimation. Nine key factors for a decision support system for SMS cost estimation were determined by a select group of aviation management experts. These factors included: (a) regulations, (b) scope of work, (c) size of an organization, (d) WBS, (e) financial schedules, (f) cost analysis, (g) cost-benefit analysis, (h) demonstrate implementations, and (i) training.

Regulations and scope of work were perceived by the panelists as the top two important factors for a decision support system for SMS program cost estimation. The discovery of the importance of these factors was not new knowledge and were anticipated because regulations would contain the scope of program expectations from regulatory authorities (Harrington et al., 2009). The literature review provided insight to cost estimations, specifically, for the scope of aviation SMS programs (CASA, 2012; FAA, 2010d); however, the estimations varied between regulatory authorities worldwide. Variations that could be attributed to existing regulations and best practices already in place in numerous states. Although it was anticipated regulations would be an important factor for SMS cost estimation modeling, the literature review found some managers may have proceeded with SMS program implementation without a complete understanding the scope or the cost effect to their organization (Liou et al, 2008). Based on the literature review and the findings of this study, the implementation of the key factors may contribute to additional discussions on strategies for SMS program management.

Research Question 2. How could SMS project cost estimates be modeled using existing information sources in the aviation business environment? A high-level SMS project cost estimation model was developed using existing information sources for the aviation business environment. The model included tools, sources of data for labor standards, and information decision makers would be interested in before implementing SMS that could be used by decision makers and practitioners for SMS cost estimation identified by a purposeful sample of aviation management experts in project management and cost analysis for project planning. The tools were categorized into nine common themes: (a) program design, (b) process management, (c) scope of work, (d) industry best practices, (e) IT, (f) resources, (g) modeling, (h) regulatory requirements, and (i) user implementation tools. Themes associated with labor standards and sources were categorized into three common themes: (a) data sources, (b) regulatory requirements, and (c) process management. Information decision makers would be interested in before implementing SMS were categorized into 11 themes: (a) program design, (b) industry best practices, (c) leadership, (d) modeling, (e) cost analysis, (f) cost-benefit analysis, (g) data sources, (h) regulatory requirements, (i) resources, (j) responsibilities, and (k) scope of work.

The initial drivers for this study were provided in the ICAO SMS model (ICAO, 2009), specifically, the Gantt Chart-SMS Implementation Plan. The key factors previously discussed provided the baseline to understand how SMS project cost estimates could be modeled using existing information sources in the aviation business environment. A high-level framework was developed for SMS cost estimation modeling that could be used by leaders of any organization. The framework consisted of information and tools one would expect in a decision support system for SMS cost estimation, specifically, the tools for program cost estimation, data sources and knowledge of training standards as perceived by experts that could assist decision makers with program development strategies. The high-level framework included:

- Key factors for a decision support system framework.
- Knowledge of scope of work. The initial drivers for this study were provided

in the ICAO SMS model (ICAO, 2009), specifically the Gantt Chart- SMS Implementation Plan. The SMS Cost Estimation Tool (see Appendix O) provided the baseline scope of work identified in the ICAO SMS model (ICAO, 2009) WBS, adjusted for labor cost.

- Knowledge of tools that could be used in cost estimation methods, such as WBS, IT, training standards, and financial schedules.
- Knowledge of data sources that could be used in cost estimation methods, such as financial schedules.
- Knowledge of size of organization to understand resources.
- Knowledge of training standards of stakeholders. The Delphi panelists' perceptions of training standards varied between 0 and 80 hours, posited by some to only include "managers and analysts." An Estimated Cost of Training per Hour Tool (see Appendix Q) that could be referred to by decision makers and analysts for ROM training estimates was developed in this study. The ROM training estimates could then be adjusted for variables and cost drivers after a gap analysis definitively identified scope of work for specific organizations.

As previously discussed, decision support systems included the documents, knowledge, and data available to assist decision makers solve problems, complete tasks, and make decision aimed at increasing the efficiency of activities (Baldwin et al, 2010; Khataise et al., 2011). According to Conboy (2010), a decision support system should include knowledge of financial costs so that decision makers can commit the resources needed to ensure a successful program. The development of two cost estimation tools contributed to the knowledge of the ICAO SMS model and a theoretical answer for SMS program financial cost. Benefits of obtaining knowledge of the ICAO SMS model, in the context of ROM baseline labor costs, may assist decision makers in planning efforts for program designs and reduce financial risk in their respective industrial sectors (Lu, Young, et al., 2011). Understanding ROM baseline labor costs and financial data collection needs may help decision makers design SMS programs and obtain true business benefits (Cox & Flouris, 2011). The data derived from the study addressed the need for a management decision-making model for SMS cost estimation that was conceptually grounded in quality management (Anderson et al., 1994; Avers et al., 2011) and ABC principles (Cox & Flouris, 2011; Tsai et al., 2008). The model may then be applied to an ongoing framework to conduct cost-benefit analysis for safety initiatives and ROI after program implementation.

Recommendations

SMS programs have not always been implemented in the aviation industry, as actual program costs could not be determined comprehensively and definitively (Avers et al., 2011; Rosenkrans, 2012; Lu, Young, Schreckengast, & Chen, 2011). Managers may use information for decision making related to design and planning quality, customer service, assessment, and continuous improvement (Cooper & Kaplan, 1999). Obtaining knowledge of the key factors and how SMS project cost estimates were modeled facilitated organizational learning and continuous improvement processes and contributed to the scholarly and practitioner literature of the theory of quality management and ABC principles to stimulate further discussion and approaches of the management methods. Recommendations offered for both practice and future research resulted from the study and by responses of the Delphi panelists, some supported by previous research.

Recommendations for practice. Three recommendations were offered for professional practice: (a) rulemaking (regulatory) improvements that will support the quality of data available for research, (b) improvements to guidance material that will support SMS program strategies, and (c) IT improvements that will support future analysis of benefits of SMS programs. The recommendations, along with supporting findings from this study and the literature, are briefly discussed.

Recommendations for rulemaking improvement. Two separate recommendations for rulemaking are offered: (a) improvement of cost estimation methodology, and (b) reporting requirements for data improvement. First, regulations were identified as the most important factor for a decision support system for SMS cost estimation with cost analysis the sixth in importance. Panelist comments related to tools for cost estimations suggested a need to improve the methodology of cost estimations in proposed rulemaking. In relation to regulation cost estimations, Harrington et al. (2009) found the difficulty in determining the baseline and incomplete compliance drove the quality of errors with cost estimations. Second, governing authorities may consider including reporting requirements of financial data for SMS programs, particularly regulatory requirements for collecting financial cost data related to accidents and incidents. Current data collections in the aviation industry have been beneficial for research and the advancement of understanding safety management. Panelists' perceptions of why the business case for benefits of safety programs were difficult to analyze and how to overcome barriers to make a business case for SMS programs suggested the need to include financial data for accidents and incidents, which may prove beneficial to help practitioners and regulatory authorities fully realize SMS benefits.

Panelists' perceptions of the possible advantages of "comparing the cost associated with an incident and/or accidents," as well as, aviation safety literature (Liou et al, 2008) supported this recommendation. The recommendations were also supported by the literature in other industries where the lack of financial data were found barriers that hindered the discovery of knowledge of the business benefits of QMS programs (Kumar & Balakrishnan, 2011; Levine & Toffel, 2010; McGuire & Dilts, 2008), the foundation of SMS.

Guidance improvement. According to Harrington et al. (2009), incomplete compliance should be expected and program cost estimations will continue to be difficult to determine until project baselines and scope of work are comprehensively and definitively defined. With the lack of definitive regulations concerning SMS programs in the United States, advisory circulars will need additional attention, which was supported by panelists' comments that advisory circulars "give better scope." Many of the suggestions for new questions or modifications to existing questions for this study were judged to not to be within the scope of this research, but suggested additional strategies are needed related to SMS program design and process management issues. Of significant interest were suggestions by panelists to understand the extrinsic factors in SMS cost estimation, as well as, the risk factors that practitioners might overlook during program design and standards for SMS training would be of interest to practitioners.

Safety professionals have suggested the inclusion of ABC principles to collect financial data as a means to make a business case for safety initiatives (Jallon et al., 2011; Rosenkrans, 2012; Tsai & Hsu, 2008). Two tools were developed in this study following ABC principles that could assist decision makers and program designers address the cost aspects of planning, implementation, and contribute to the sustainment of SMS programs. The inclusion of ABC methods at the onset of program implementation can contribute to program strategies, will provide a method to adjust ROM estimates for accuracy when more detailed data are provided, and provide data necessary for future analysis of benefits. Askarany et al. (2010), Baykasoglu and Kaplanoglu (2008), and Kareem et al. (2011) found the inclusion of ABC methods was beneficial for cost estimation and project management.

Recommendations related to the improvement of the ICAO SMS guidance material are offered because the initial drivers for this study were provided in the ICAO SMS project model. From a project management perspective, the ICAO SMS model SMS Implementation Plan (ICAO, 2009, pp. 10-APP 2-11-10-APP 2-14) indicated the number of days anticipated to accomplish Phases 1 through 4 of the model. Although the ICAO SMS model indicated organizational leaders should conduct gap analysis and costing, the ICAO SMS model may mislead decision-makers if they elected not to perform a detailed analysis for both project duration and cost. To further complicate the issue, the advanced revision of the ICAO SMS project model (ICAO, 2012) did not include the full version of the SMS Implementation Plan provided in the 2009 version. In an effort to share information and lessons learned, the WBS should be included in future SMS guidance material, which was supported by the fact that participants of the current study noted decision support system data and templates that include cost and schedule estimates should be provided within guidance manuals with an explanation of the methods and assumptions. Knowledge and inclusion of information would follow continuous improvement philosophies and project management methods for successful program planning, program design, process control, and financial expenditures that researchers could use in future studies to support business, as well as, safety objectives. Information should include cost analysis methodologies for program implementation and cost-benefit analysis.

Information technology. Decision makers should consider the use of IT resources to collect financial data during the design stages of program development. Although participants in the main study identified IT software tools for SMS cost estimation modeling, participants in the preliminary study posited "IT is the backbone of the future SMS development when the DSS is used to decide a cost-effective SMS." Consideration should be given to include cost data for future analysis to fully realize SMS benefits. In a study targeting Mauritian ISO 9001-2000 certificated organizations, Wai (2011) found that IT had a substantial impact on quality management processes, which indicated IT would also have an impact on SMS processes. The literature included discussions to collect financial data to make a business case for safety initiatives (Jallon et al., 2011; Liu et al., 2009; Tsai & Hsu, 2008); yet, discussions in the safety literature have not included IT improvements, which include database design and requires more attention.

Recommendations for further research. Four recommendations for future research were offered: (a) links of safety initiatives to business advantage, (b) barriers to the collection of financial data, (c) case studies for empirical evidence of program costs, and (d) theoretical development. The recommendations for further research, along with supporting findings from this study and the literature, are briefly discussed.

Links of safety initiatives to business advantage. In the current study, regulations were ranked the top priority for a decision support system for SMS cost estimation. Some practitioners have posited the economic burden for safety oversight will shift from regulatory authorities to self-regulation by the aviation industry (Atak & Kingma, 2011; Grote, 2012; Hopkins, 2011; Lacagnina, 2009; Stoop & Dekker, 2012). The impact of regulations on the economic burden on the industry is an area for future research; however, it would be necessary to first collect the financial cost data as previously discussed. New safety challenges require development and understanding different forms of data (Oster et al., in press). The recommendation related to linking safety initiative to business advantage was supported by the literature (Cox & Flouris, 2011; Rosenkrans, 2012; Thomas, 2012) and the fact that panelists posited the benefits of SMS programs were subjective, further noting "The success of the SMS may vary due to lack of funds committed however there is still no direct correlation between SMS and prevention of an accident."

Barriers to the collection of financial data. Further research is needed to investigate barriers to the collection of financial data. The findings of the current study indicated the need for additional research to address the cost aspects of SMS programs and followed recent work by others (Lu, Schreckengast, et al. 2011; Wang, 2013).

Case studies for empirical evidence of program costs. There were no known case studies of aviation SMS program costs. Further research could include *ex post* analysis with case studies of organizations implementing SMS through all four phases; however, it is anticipated this type of study might be limited due to the time necessary for full program implementation. An ex post analysis of SMS program costs might be underestimated, particularly if SMS was integrated into existing management programs and resource expenditures for all SMS efforts were not effectively accounted for ex post.

Theory development. The cornerstone for SMS program design began with QMS concepts (Mizutani, 2010). Although over one million organizations worldwide have obtained QMS certifications (Heras-Saizarbitoria & Boiral, 2013), theoretical development has not progressed. Managers must understand QMS concepts, and the theoretical underpinnings of the concepts, before SMS programs could be expected to produce benefits. Additional research is necessary to advance the theory of quality management, possibly using a conceptual research approach following work by Holschbach and Hoffmann (2010). The advancement of the theory of quality management could improve process management practices, internal and external cooperation concepts for both organizations and regulators, and contribute safety process management practices and project management activities. According to Anderson et al. (1994), the theory of quality management facilitates organizational learning and continuous improvement processes, which organizational leaders must articulate.

Conclusions

Safety management is a major issue in the aviation industry and professionals in the field of aviation safety management have only recently begun to use advanced business management practices to address viable ways to determine the cost of safety initiatives in this complex environment. Although SMS are built on the foundation of quality management principles, actual program costs investments have not been determined comprehensively and definitively. The difficulty in quantifying the cost of safety initiatives may be attributed to aviation authorities and organizations not collecting financial data with the intention to conduct cost-benefit analysis or trend analysis (Briciu & Capusneanu, 2010; Wang et al., 2013). The data derived from the study addressed the need for a management decision-making model for SMS cost estimation that was conceptually grounded in quality management (Zu et al., 2013) and ABC principles (Baykasoglu & Kaplanoglu, 2008; Novak et al., 2011). The current study included a three-round Delphi study to collect the opinions of a select group of individuals in the aviation industry with expertise in project management and cost analysis for project planning. The Delphi panelists identified key factors, tools, sources of data for labor standards, and information decision makers would be interested in before implementing SMS that could be used to assist in the development of a decision support system for SMS cost estimation. The panelists identified nine key factors for a decision support system framework: (a) regulations, (b) scope of work, (c) size of an organization, (d) work breakdown structure, (e) financial schedules, (f) cost analysis, (g) cost benefit analysis, (h) demonstrate implementations, and (i) training.

The current study differed from other studies in that it explored how SMS cost estimates may be modeled using existing information sources to provide decision makers with a framework for SMS program strategies. Cost importance to an organization was emphasized in the literature in the context of how organizations use various tools for monitoring and measuring project performance such as dashboards and balanced scorecards (Briciu & Capusneanu, 2010). The tools, sources of data for labor standards, and information decision makers would be interested in before implementing SMS is knowledge which may assist decision makers in planning efforts for program designs and assist decision makers in reducing financial risk in their respective industrial sectors. The

Delphi panelists posited the benefits of SMS have been difficult to analyze because benefits are subjective. The findings were somewhat consistent with previous research (Thomas, 2012) on the effectiveness of SMS across multiple industries in which many studies had only "measured subjective perceptions of safety rather than objective measures" (p. iii). The conclusions reached as a result of panelist responses and the literature review provided the basis for the development of a decision support system for aviation SMS cost estimation. The decision support system consists of a high-level framework and decision support system tools developed as a result of the exploring how SMS cost estimates may be modeled. This framework may be the first step necessary to obtain financial objective measures for future research study.

The focus of the study was an exploration of decision-making frameworks for SMS cost estimation systems in the context exclusively identified in the ICAO SMS program model (2009) from the perspective of theory of quality management (Anderson et al., 1994). Although the ICAO SMS program model identified key factors such as task time standards, it did not include other key factors typically needed for program management. The evolving theory of quality management provided the theoretical foundation in this study to obtain knowledge to facilitate organizational learning and continuous improvement processes to stimulate further discussion and approaches of the safety and quality management methods.

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Appendices

Appendix A:

Reprint Permissions

Reprint Permission to Use Figure Titled Elements of Customer Value

RE: Permission to use figure

[illegible]
Sent: Tuesday, August 14, 2012 6:22 AM
To: [illegible]

Dear Nina
Many thanks for your email. Please allow me to introduce myself. My name is Laura Jenkins and I am the Rights Manager here at Emerald. I am pleased to say that subject to full referencing I can grant you free permission to include the material detailed below within your dissertation

- Figure 4 from Ashish Kothari, Joseph Lackner (2006) "A value based approach to management", Journal of Business & Industrial Marketing, Vol. 21 Iss: 4, pp.243 - 249

Please note however that if in the future you publish your dissertation commercially you will need to clear permission again

Good luck with your dissertation

Kind Regards

Laura Jenkins
Rights Manager
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Emerald is a leading independent publisher of global research with impact in business, society, public policy and education

Reprint Permission to Use ICAO Safety Management Manual (Doc 9859)

From: Duncan, Nina (JSC-CC211) [mailto:nina.duncan-1@nasa.gov]
Sent: 24-Sep-12 1:35 PM
To: Fabrici, Ondrej
Subject: RE: Document permissions

Thank you for your fast response

I would like permission to provide an electronic copy of ICAO's Safety Management Manual, Doc 9859, 2nd edition. I understand the advanced copy of the 3rd edition is available but it does not include a complete work breakdown structure (data) needed for this study

My proposed study is currently titled
A Delphi Study of Decision Support Systems for Aviation Safety Management Program Cost Estimation

The purpose of the study is to identify key factors in the use of a decision support system framework for SMS program cost estimation. Specifically, it will explore how SMS cost estimates may be modeled using existing information sources to provide decision makers with a framework for SMS program strategies. The study design will employ a modified Delphi technique to allow for a panel of 10 aviation industry experts to contribute a critical knowledge base to the proposed study. In addition, a preliminary assessment will be conducted by at least 4 aviation industry professionals and stakeholders familiar with SMS programs to evaluate the Delphi questions and determine the validity of the initial drivers provided in the ICAO SMS project model

I have attached a copy of Chapter 1 of my dissertation proposal for your review. Please let me know if you have any problems opening the document or need any other information

Nina K. Duncan

Lee-Fung, Margaret [MLeeFung@icao.int] on behalf of Fabrici, Ondrej [OFabrici@icao.int]
Sent: Wednesday, November 21, 2012 7:55 AM
To: Duncan, Nina (JSC-CC211)
Cc: Jian, James [JJian@icao.int]; Fabrici, Ondrej [OFabrici@icao.int]; Office of the Director ADB [ADB@icao.int]; Lee-Fung, Margaret [MLeeFung@icao.int]; Forbin, Sherrik [SForbin@icao.int]

(Ref.: E RDM46970, File: A3/9)

Dear Mrs. Duncan,

I refer to our communication on the subject matter and would like to advise you that ICAO have no objection if ICAO's Safety Management Manual (Doc 9859), 2nd edition, is used for the purpose and in the way you indicated in your messages of 5 and 21 September 2012. However, when parts of the subject ICAO material are reproduced in your study, in accordance with ICAO's Publications Regulations, the following conditions shall apply:

a) no change shall be made in the wording or content of the reproduced parts without express authorization by ICAO;
b) suitable accreditation shall accompany the extracts reproduced with an indication that they have been reproduced with the permission of ICAO; and
c) one copy of your study, when finalized, shall be forwarded to ICAO, without charge, for its files.

We hope that the above conditions will be acceptable to you.

Yours sincerely,

Ondrej Fabrici
Chief, Records & Distribution Management Section
for Fang Liu
Director, Bureau of Administration & Services
International Civil Aviation Organization (ICAO)
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Appendix B:

Researcher E-mail Script for Preliminary Assessment Participation

Date: (To be provided)

Subject: Research Study Preliminary Assessment Participation

To: (Preliminary Assessment Team Member)

Hello (Participant's Name)

A group of experts is needed to perform a preliminary review of a research study being conducted for a dissertation at Northcentral University in Prescott, Arizona. Your professional opinion is valuable to this research study. You are invited to provide your opinions of the initial questionnaire that will be used in the study and suggested qualifications of study participants.

The research study is titled:

A DELPHI STUDY OF DECISION SUPPORT SYSTEMS FOR AVIATION SAFETY MANAGEMENT PROGRAM COST ESTIMATION

Information regarding the study and the instructions for preliminary assessment are attached. The electronic files are titled:

- Preliminary Assessment Information and Instructions.doc
- Delphi Round 1 Questionaire.doc

If you are unable to participate at this time, I would appreciate if you would let me know so I can remove you from my contact list.

The researcher conducting this study is Nina Duncan, a PhD candidate at Northcentral University. This research is being conducted under the direction of Dr. Robin Throne, Chair of the dissertation. If you have any questions, my contact information is XXX-XXX-XXXX (cell) or XXX-XXX-XXXX (home).

Appendix C:

Preliminary Assessment Information and Instructions

A DELPHI STUDY OF DECISION SUPPORT SYSTEMS FOR AVIATION SAFETY MANAGEMENT PROGRAM COST ESTIMATION

Background Information

The purpose of the study is to identify key factors in the use of a decision support system framework for Safety Management System (SMS) program cost estimation. This study will explore how SMS cost estimates may be modeled using existing information sources to provide decision makers with a framework for SMS program strategies. The focus of the study will be an exploration of decision-making frameworks for SMS cost estimation systems in the context exclusively identified in the International Civil Aviation Organization (ICAO) SMS program model (2009). Although the ICAO SMS program model identifies key factors such as task time standards it does not include other key factors typically needed for program management and transparency of safety and financial risks.

Study Procedure

The study will use a Delphi technique based on the thought that decision makers are interested in gaining insight from experts and their the contributions are critical to decision making. Delphi panelists will be asked to review the ICAO Safety Management Manual, Technical document 9859 AN/474, 2nd edition, dated 2009. This document contains a Gantt chart that identifies task-specific activities in the form of a work breakdown structure (WBS) typically used in project management that will be used in the study. A review of this document is anticipated to take approximately two hours. The document may be retrieved from:

http://www.icao.int/safety/ism/Guidance%20Materials/DOC_9859_FULL_EN.pdf

or by accessing the Federal Aviation Administration website at:

http://www.skybrary.aero/bookshelf/books/644.pdf

Data will be obtained using an online questionnaire through three Delphi rounds to identify key parameters and methods for managing the total cost of SMS program development using activity-based costing (ABC) principles. The first questionnaire will provide open-ended questions to seed participation and elicit communication. The results of each questionnaire will then be prepared and provided to panelists as feedback. The questionnaires will be sent to experts in three rounds to collect their opinions regarding key factors such as business applications, labor standards and sources, schedule standards, and other information to be found in a decision support system framework for SMS cost estimation.

Participation Confidentiality

Although your participation in this preliminary assessment is voluntary, confidentiality is assured and no personnel information will be disclosed for those willing to contribute their time to participate. All personal information and the name business affiliations will not be used. Persons willing to contribute their time for this assessment will be given the option to be acknowledged for their contribution to the study.

Risks and Benefits of Participation in the Study

The problem address by this study is that safety management system programs have not always been implemented in the aviation industry as actual program costs could not be determined comprehensively and definitively. The benefits of participation include contribution to this industry problem. Your participation will also help the researcher complete the dissertation requirements. There are no known risks associated with participation in this study.

First Round Questionnaire

The first round questionnaire (attached) will provide open-ended questions to seed participation and elicit communication from participants in the study. Initial questions in a Delphi study should focus on the desired objectives but not bias the responses. You are asked to provide a preliminary assessment of the first round of questions to discover its potential to provide meaningful information and expectations prior to study implementation.

Participant Qualifications

Your opinion of Delphi panel participant qualifications is necessary since the selection of experts is critical to the Delphi method and serves to provide validity to the proposed study. The study is designed where Delphi panel members is defined by a small group of experts in a preliminary assessment.

Successful Delphi studies typically include participants who have a strong interest in the results of the study. Careful attention will be placed on selecting Delphi expert panelists who have demonstrated an interest in SMS programs.

The selection draw shall come from personnel who work at different companies and industrial aviation sites. Delphi expert panelists may be selected from backgrounds which may include government agencies other than the Federal Aviation Administration (FAA). Personnel employed by the FAA will be excluded from the proposed study since the FAA provides regulatory oversight for the industry and may induce biases that could threaten the validity of the study.

The study proposes the following participant qualifications:

1. Aviation management experts who possess a broad understanding of project management and project cost analysis.

2. Have at least 10 years expertise in project management and cost analysis for project planning.

3. Attended at least two safety management seminars or received at least 40 hours of training related to SMS programs.

4. Shall be computer literate (Microsoft Office applications and e-mail correspondence).

5. Identified by their professional peers as having a distinct level of expertise to represent the aviation field.

6. Shall not be employed by the Federal Aviation Administration (FAA).

ICAO SMS Project Model

The ICAO SMS project model provides data in the format of a task specific work scope that follows Activity Based Costing principles. Please provide your opinions of the initial drivers provided in the ICAO SMS project model that would assist in the development of a decision support system for SMS program cost estimation.

Instructions for Preliminary Assessment

Please provide your opinions of the first round questionnaire, participant qualifications, and the ICAO SMS project model. You may provide your opinions in any format (e-mail, word document, hand written response).

Contact Information

The researcher conducting this study is Nina Duncan, a PhD candidate at Northcentral University. This research is being conducted under the direction of Dr. Robin Throne, Chair of the dissertation. If you have any questions, my contact information is XXX-XXX-XXXX (cell) or XXX-XXX-XXXX (home).

Appendix D:

Delphi Round One Questionnaire

A DELPHI STUDY OF DECISION SUPPORT SYSTEMS FOR AVIATION SAFETY MANAGEMENT PROGRAM COST ESTIMATION DELPHI ROUND ONE QUESTIONNAIRE

Please answer the following questions that you believe are necessary for decisions support system framework for Safety Management System (SMS) program cost estimation. Please refer to ICAO Publication Technical Document 9859 AN/474 (2nd edition, dated 2009) to answer these questions. The document may be retrieved from:

http://www.icao.int/safety/ism/Guidance%20Materials/DOC_9859_FULL_EN.pdf

or by accessing the Federal Aviation Administration website at:

http://www.skybrary.aero/bookshelf/books/644.pdf

Please clarify or expand your answers with additional responses to explain your opinion. If possible, please provide technical or scholarly references or expand on your past experience that supports your opinion.

1. What tools would you expect to use to assist in the development of a decision support system for safety management system cost estimation?

2. What labor standard and sources would you use to develop a decision support system for safety management system cost estimation?

3. What schedule standard, in the context of labor hours, would you use to develop a decision support system for safety management system cost estimation?

4. What other information would a decision maker responsible for the implementation of a safety management system program in the aviation industry be interested in knowing before implementing this type of program?

5. What new questions or modifications of existing questions for this study would you recommend?

Appendix E:

Professional Organizations Requested to Announce Study

Managers of several aviation and professional organizations, including safety consultants, were asked to post notification of the study to their websites to generate interest in the study. Following is a list of possible sponsors for participant solicitation for this study with their associated websites.

Sponsor name	Internet address
Aircraft Owners and Pilot Association (AOPA) Air Safety Foundation	http://www.aopa.org/asf/
Air Traffic Control Association (ATCA)	http://www.atca.org/
Airlines for America (A4A), formerly Air Transport Association	http://www.airlines.org/
Aviation Maintenance Technology (AMT) Society	http://www.amtonline.com/
Curt Lewis and Associates, Aviation Safety Consultants	http://www.curt.lewis.com
Federal Aviation Administration Facebook	http://www.facebook.com/FAA
Federal Aviation Administration Safety Team (FAAST)	http://www.faasafety.gov
Flight Safety Foundation	http://flightsafety.org/
International Airline Safety Consulting	http://www.ghsaviationgroup.aero/
International Society of Air Safety Investigators (ISASI)	http://www.isasi.org/
National Aeronautics and Space Administration, Safety Office	http://hsi.arc.nasa.gov/index.php
National Transportation Safety Board (NTSB)	http://www.ntsb.gov/
National Air Traffic Controllers Association	http://www.natca.net/
Professional Aviation Maintenance Association (PAMA)	http://www.pama.org/
Safety Operating Systems	http://www.safeopsys.com/
University Aviation Association	http://www.uaa.aero/

Appendix F:

Study Announcement and Participant Recruitment

Subject: Study Participant Recruitment

To: (Professional Organization)

Hello,

I am a student at Northcentral University and am currently working on a study related to aviation safety management programs. I am looking for people who would be willing to participate in the study. I would like (Organization) to help me recruit people for this study by posting the notice to your website. In return, I will be happy to recognize your help in the research document. Please feel free to call me at either of the phone numbers below or e-mail me if you need any additional information.

Thank you for your support.

Nina K. Duncan
Doctorate Candidate
Cell: XXX-XXX-XXXX
Home: XXX-XXX-XXXX
E-mail: XXXX

Study Participant Recruitment Solicitation

People who have skills in project management and cost analysis for project planning are needed to be a part of a research study that will be conducted at Northcentral University. In addition, these people need to be familiar with aviation safety management programs.

If you know of anyone with these skills, please contact ninaduncan@ymail.com or call XXX-XXX-XXXX.

Appendix G:

Researcher E-mail Script for Delphi Panelist Participation

Date:

Subject: Delphi Study of Decision Support Systems for Aviation Safety Management Program Cost Estimation

To: (Delphi Panel Participant)

Hello (Panelist Name),

I am a student at Northcentral University and am currently working on a study about aviation safety management programs. I am looking for people who would be willing to be a part of the study. I received your name from one of your peers who explained you were an expert in project management and cost analysis for project planning. Your expertise and opinions are important to my study so I would like to formally invite you to be part of this study. Please take a minute to review the attached information to learn more about the study and feel free to ask questions before agreeing to participate.

Thank you in advance for your help with this study.

Sincerely,
Nina Duncan
E-mail: XXXX
Cell: XXX-XXX-XXXX

Appendix H:

Informed Consent Letter

A DELPHI STUDY OF DECISION SUPPORT SYSTEMS FOR AVIATION SAFETY MANAGEMENT PROGRAM COST ESTIMATION

Your opinion is vital to this study. Please review this informed consent letter and feel free to ask questions before agreeing to be a part of this study.

Background Information

The purpose of the study is to identify key factors in the use of a decision support system framework for Safety Management System (SMS) program cost estimation. A decision support system is a management tool created by experts that can be used by others to increase efficiency and to help them make decisions. Decision support system models include the documents, knowledge, and data available to help managers solve problems. This study will look at ideas for SMS cost estimation systems with the scope limited to the model provided by the International Civil Aviation Organization (ICAO). Although the ICAO SMS program model identifies key factors such as task time standards it does not include other key factors typically needed for program management and transparency of safety and financial risks.

Procedure

This study will consist of three rounds of questions that will be e-mailed directly to you to allow you time to review and answer each question. Initially you will be asked to answer a few questions about yourself to make sure all panel members meet the study design criteria.

In the first round of questions, you will be asked to answer several open-ended questions and will be given the chance to suggest more questions, or changes to the existing questions. Since the first round of questions has several open-ended questions, it is likely to take about 60 minutes to complete. In addition, you will be asked to review the ICAO Safety management Manual, Technical document 9859 AN/474, 2nd edition, dated 2009, if you have not previously done so. A review of this document is expected to take about two hours. The ICAO document may be retrieved from

http://www.icao.int/safety/ism/Guidance%20Materials/DOC_9859_FULL_EN.pdf

or by accessing the Federal Aviation Administration website at:

http://www.skybrary.aero/bookshelf/books/644.pdf

The comments of all Delphi panelists will be consolidated after each round to let you know the responses of the other participants. In the second and third round of questions, you will be asked to rate the responses from the first round of questions and is estimated to take about 30 minutes to complete.

Before you agree to be a part of this study, please consider the time commitment since it is important for you to complete all three rounds for the data to be useful in this study.

Confidentiality

Your personal information will remain anonymous during the study. No participant's names or the name of their business affiliation will be used.

Voluntary Nature of the Study

Your participation in the study is voluntary, so you may withdrawal from the study at any time. It is understood your time is valuable but your help will not go unnoticed. All participants will be given the chance to be recognized for their in input in the study document.

Risks and Benefits of Participation in the Study

There are no known risks associated with participation in this study. This study looks at the problem that safety management system programs not having been appropriately implemented in the aviation industry due to the inability to comprehensively and definitively determine actual program costs. Your participation in this study will greatly enhance the possibility of rectifying this problem and will also help the researcher complete the dissertation requirements.

Contact Information

The researcher conducting this study is Nina Duncan, a PhD candidate at Northcentral University under the direction of Dr. Robin Throne, Chair of the dissertation. If you have any questions, please contact:

Nina K. Duncan E-mail: XXXX
Dr. Robin Throne E-mail: XXXX

Statement of Consent

The purpose of this informed consent letter is to provide you information, so that you can decide if you would like to participate in the study. Your consent indicates you understand the procedures and results of being a part of the study. Please complete the brief questionnaire that follows and acknowledge your consent to be a part of this study via e-mail correspondence with the researcher. The questionnaire is provided in a Microsoft Word format to allow you to type in, bold, underline, or highlight your answers. Please save the file to ensure your responses are captured before returning it to the researcher. Your participation in this study is greatly appreciated.

Demographic Questionnaire

Please provide the following information about yourself. This information is needed to make sure all panel members meet the study design criteria. It will also be used to cross-tabulate responses to help the researcher with data analysis.

Please type in, bold, underline, or highlight the appropriate information. If desired, you may also print out the questionnaire, fill it in, and return it to the researcher.

Name: ____________________

Organization: ______________________

Organization Location: _______________________

Position/Title: _______________________

E-mail: _______________________

Other contact information: _______________________

1. Which of the following describes your organization's operation?
   - A. Part 91, General Aviation
   - B. Part 121, Air Carrier Operations
   - C. Part 135, Commuter
   - D. Part 139, Airport Operations
   - E. Part 145, Repair Station
   - F. Federal Aviation Administration
   - G. International Civil Aviation Organization
   - H. Other government agency
   - I. Professional Safety Consultant
   - J. Academics
   - K. Other (please specify) _____________

2. How many years have you worked in the aviation industry? _____ Years

3. Which of the following describes your position of employment?
   - A. First-line specialist
   - B. First-line supervisor
   - C. Middle management
   - D. Upper management
   - E. Other (please specify) _____________

4. In your opinion, are you proficient with the use of computer applications? (Microsoft Office and e-mail correspondence? YES or NO

5. Which of the following describes your expertise? (Please indicate all that apply).

   A. Airport Operations
   B. Engineering
   C. Flight Operations
   D. Management
   E. Quality
   F. Safety
   G. Other (please specify) ______________

6. In your opinion, do you possess a broad understanding of project management and project cost analysis? YES or NO

7. How many years have you been involved in project management and cost analysis for project planning? _____ Years

8. Please provide an example of your experience in project management and cost analysis for project planning.

   ____
   ____
   ____
   ____

9. Have you attended at least two safety management seminars or received at least 40 hours of training related to SMS programs? YES or NO

Appendix I:

Researcher E-mail Script for Round 1

From: Nina K. Duncan

To: Delphi Panelist

Subject: Delphi Study of Decision Support Systems for Aviation SMS Program Cost Estimation- DELPHI ROUND ONE

Hello (Panelist Name),

Thank you for agreeing to participate in this study regarding decision support system frameworks for Safety Management System program cost estimation. Please complete *Round One Questionnaire* by (date). Early submissions are welcome. If you have any questions or need clarification please e-mail or contact me at XXX-XXX-XXXX (cell) or XXX-XXX-XXXX (home).

Thank you very much for your participation.

Sincerely,
Nina K. Duncan
Northcentral University

Appendix J:

Researcher E-mail Script for Round 2

From: Nina K. Duncan

To: Delphi Panelist

Subject: Delphi Study of Decision Support Systems for Aviation SMS Program Cost Estimation- DELPHI ROUND 2

Hello (Panelist Name),

Thank you for your prompt attention and response to the *Round One Questionnaire*. All (number) Delphi panelists have responded and we are ready to proceed to round two. The responses to round one were collected and randomly organized. In round two you will respond to each individual responses from round one.

Please complete *Round Two Questionnaire* by (date). Early submissions are welcome. If you have any questions or need clarification please e-mail me or contact me at XXX-XXX-XXXX (cell) or XXX-XXX-XXXX (home). Thank you again for agreeing to participate in this study regarding decision support system frameworks for Safety Management System program cost estimation.

Sincerely,
Nina K. Duncan
Northcentral University

Appendix K:

Researcher E-mail Script for Round 3

From: Nina K. Duncan

To: Delphi Panelist

Subject: Delphi Study of Decision Support Systems for Aviation SMS Program Cost Estimation- DELPHI ROUND 3

Hello (Panelist Name),

Thank you for your prompt attention and response to the *Round Two Questionnaire*. All of the Delphi panelists have responded and we are ready to proceed to round three. The responses to round two were collected and randomly organized. In round three you will respond to each individual responses from round two.

Please complete *Round Three Questionnaire* by (date). Early submissions are welcome. If you have any questions or need clarification please e-mail me or contact me at XXX-XXX-XXXX (cell) or XXX-XXX-XXXX (home). Thank you again for agreeing to participate in this study.

Sincerely,
Nina K. Duncan
Northcentral University

Appendix L:

Delphi Panel Demographic Characteristics

Table L1

Professional Position

Position	Frequency	Percent
First-line specialist	1	25
Middle management	1	25
Upper management	2	50
Academic	1	25

Note: *N*=4; multiple types reported.

Table L2

Aviation Experience

Aviation experience (Years)	Frequency	Percent
15-19	1	25
> 35	3	75

Note: *N*=4.

Table L3

Length of Experience in Project Management and Cost Analysis

PM/CA experience (Years)	Frequency	Percent
15-19	2	50
20-24	3	50

Note: *N=4*; PM/CA = Project management and cost analysis.

Table L4

Aviation Operation

Type operation	Frequency	Percent
Part 91, General aviation	2	50
Part 141, Pilot school	2	50
Part 142, Training center	1	25
Government agency	1	25
Consultant	2	50
Academics	1	25

Note: *N*=4; multiple types reported.

Table L5

Aviation Expertise

Type of expertise	Frequency	Percent
Airport operations	3	75
Engineering	3	75
Flight operations	4	100
Management	3	75
Quality	2	50
Safety	3	75

Note: *N*=4; multiple types reported.

Appendix M:

Example of Knowledge Resource Nomination Worksheet

Name of Participant	Participant Phone #	Email	Organization	Title/ Background	Years in Industry	PM & CA Skill	Yrs Exp	Type of PM & CA Exp	Verify	SMS Training	Computer Skills	Delimitation
						PM & CA	10		Yes/No	Yes/No	Yes/No	Yes/No
						PM & CA	10		Yes/No	Yes/No	Yes/No	Yes/No
						PM & CA	10		Yes/No	Yes/No	Yes/No	Yes/No

Panel selection criteria

PM & CA Skill	Experience with project management and cost analysis for project planning	Project Mgmt
Yrs Exp	Possess at least 10 years expertise in project management and cost analysis for project planning	Cost Accounting
Computer Skills	Shall be computer literate (as a minimum, proficient with Microsoft Office tools [Word, excel] and e-mail communications)	

Demographics

Years in Industry	Number of years participant employed in the industry
Operator	Industry sector
Expertise	Specific area of expertise in the aviation industry
SMS Training	Attended at least two safety management seminars or received at least 40

Delimitations:

Organization/ Operator	Personnel employed by the FAA & ICAO were excluded from the preliminary assessment. Personnel employed by the FAA were excluded from the Delphi study.
Organization/ Operator	Selection of one individual employed from a single company or industrial aviation site

Figure M1. Example of Knowledge Resource Nomination Worksheet (page 1 of 3). A KRNW was used as an administrative tool to track responses to the participant solicitation following Delbecq et al. (1975), Keeney (2010), and Okoli & Pawlowski (2004). The figure was created by N. Duncan using Microsoft Excel software.

Operation	Position	Expertise	Rank	Participant Code	Date E-mail Solicitation Sent	Responded to Solicitation	Informed Consent Filed	Follow-up	Date E-mail Round 1	Responded to Round 1	Data Round 1 Filed	Other Info Round 1

Part 91 General Aviation	First-line specialist	Airport Operators
Part 121 Air Carrier	First-line supervisor	Engineering
Part 135 Commuter	Middle Management	Flight Operations
Part 139 Airport Operators	Upper Management	Maintenance
Part 145 Repair Station	CEO	Management
Academics		Quality
Other		Other

Figure M2. Example of Knowledge Resource Nomination Worksheet (page 2 of 3). A KRNW was used as an administrative tool to track responses to the participant solicitation following Delbecq et al. (1975), Keeney (2010), and Okoli & Pawlowski (2004). The figure was created by N. Duncan using Microsoft Excel software.

Date E-mail Round 2	Responded to Round 2	Data Round 2 Filed	Other Info Round 2	Date E-mail Round 3	Responded to Round 3	Data Round 3 Filed	Other Info Round 3	Date E-mail Results	Consent to Acknowledgment

Figure M3. Example of Knowledge Resource Nomination Worksheet (page 3 of 3). A KRNW was used as an administrative tool to track responses to the participant solicitation following Delbecq et al. (1975), Keeney (2010), and Okoli & Pawlowski (2004). The figure was created by N. Duncan using Microsoft Excel software.

Appendix N:

Round 2 Questionnaire

A DELPHI STUDY OF DECISION SUPPORT SYSTEMS FOR AVIATION SAFETY MANAGEMENT PROGRAM COST ESTIMATION DELPHI ROUND TWO QUESTIONNAIRE

The questions for Round 2 were built on the foundation of the responses in Round 1. Please answer the following questions related to SMS decision support systems for SMS cost estimation. Answer each question assuming an organization has not implemented any elements of an SMS program and all items suggested in the ICAO SMS program model work breakdown structure (WBS) apply.

A SMS Cost Estimation Tool is provided with Round 2 to stimulate thinking and further discussion on how project cost estimates can be modeled using existing information sources in the aviation business environment. The SMS Cost Estimation Tool was created by the researcher by transferring the ICAO SMS program model work breakdown structure (WBS) into a Microsoft Excel format.

The following statements are related to **tools** you would expect to use in a decision support system for safety management system cost estimation. Please mark 'X', circle, bold, or highlight one of five choices: (Strongly Agree, Agree, Neither Agree or Disagree, Disagree, or Strongly Disagree) that closely represents your opinion. Please provide justification or additional comments for your opinion, if applicable.

1. Work Breakdown Structure (WBS). The WBS provides the scope of work necessary to accomplish cost and schedule estimations.

   __ Strongly Agree
   __ Agree
   __ Neither Agree or Disagree
   __ Disagree
   __ Strongly Disagree

   Justification or comments

   ____

   ____

2. The regulatory requirements are important in assessing the scope, scalability, and implementation of SMS.

   __ Strongly Agree
   __ Agree

__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

3. The size of operation is important in assessing the scope, scalability, and implementation of SMS.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

4. An extensive cost analysis should be conducted prior to implementing a safety program in order to understand expenses and demonstrate benefits.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

5. A cost benefit analysis should be conducted prior to implementing a safety program in order to understand expenses and demonstrate benefits. It was noted that the ICAO SMS Document did not include cost/benefit as an item in the SMS implementation plan. A cost benefit analysis would be extremely nebulous; a short-term, even long-term wins can be wiped out with one event.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

6. Microsoft Excel software can be used to develop cost estimates building from the project Work Breakdown Structure (WBS).

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

7. Microsoft Project software can be used to develop cost estimates building from the project Work Breakdown Structure (WBS).

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

8. Self-developed programs are tools you would expect to use in a decision support system for safety management system cost estimation.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

9. A Project Evaluation and Review Technique (PERT) analysis and sharing industry best practices are tools you would expect to use in a decision support system for safety management system cost estimation. A PERT

analysis includes three time estimates for each activity: (a) optimistic, (b) most likely, and (c) pessimistic. This enables the generation of comparative paths. Also, PERT allows slack time to be computed for activities not on the critical path. This assists decision making around the reallocation of resources and schedules. PERT is commonly used when there is a lack of estimate data or little prior experience with a similar project.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

10. For organizations that have limited financial resources, a calendar may be used as a tool for project planning.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

11. Experts and company knowledge are tools you would expect to use in a decision support system for safety management system cost estimation.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

12. FAA SMS material is a tool you would expect to use in a decision support system for safety management system cost estimation.

    __ Strongly Agree
    __ Agree
    __ Neither Agree or Disagree
    __ Disagree
    __ Strongly Disagree

    Justification or comments

    ____

    ____

13. Flight assessment, hazard reporting systems, and internal evaluation program are tools you would expect to use in a decision support system for safety management system cost estimation.

    __ Strongly Agree
    __ Agree
    __ Neither Agree or Disagree
    __ Disagree
    __ Strongly Disagree

    Justification or comments

    ____

    ____

14. Metrics are tools you would expect to use in a decision support system for safety management system cost estimation.

    __ Strongly Agree
    __ Agree
    __ Neither Agree or Disagree
    __ Disagree
    __ Strongly Disagree

    Justification or comments

    ____

    ____

15. Similar complex projects are tools you would expect to use in a decision support system for safety management system cost estimation.

    __ Strongly Agree
    __ Agree
    __ Neither Agree or Disagree

__ Disagree
__ Strongly Disagree

Justification or comments

____

____

16. SMS training is a tool you would expect to use in a decision support system for safety management system cost estimation.

__ Strongly Agree
__ Agree
__ Neither Agree or Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

The next five questions are related to **labor and schedule standards** used in project management. Please mark 'X', circle, bold, or highlight **one** of four choices: (Not Important, Somewhat Important, Very Important, or Critical) that closely represents your opinion. Please provide justification or additional comments for your opinion, if applicable. Refer to the SMS Program Cost Estimation Tool to answer these questions.

17. Collective Bargaining Agreements are sources of data that could be used for program cost estimation modeling.

__ Not important
__ Somewhat important
__ Very important
__ Critical

Justification or comments

____

____

18. Company standards are sources of data that could be used for program cost estimation modeling.

__ Not important
__ Somewhat important
__ Very important
__ Critical

Justification or comments

____

____

19. The U.S. Bureau of Labor Financial Schedules are sources of data that could be used for program cost estimation modeling.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____

    ____

20. Labor hours for the safety officer are sources of data that could be used for program cost estimation modeling.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____

    ____

21. Public labor laws are sources of data that could be used for program cost estimation modeling.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____

    ____

22. Title 14 Code of Regulations, Part 121.471, *Flight time limitations and rest requirements: All flight crewmembers*, is a source of data that could be used for program cost estimation modeling.

    __ Not important
    __ Somewhat important
    __ Very important

__ Critical

Justification or comments

____

____

The following questions are related to the information a decision maker would be interested in prior to implementing a safety management program. Please mark 'X', circle, bold, or highlight **one** of four choices: (Not Important, Somewhat Important, Very Important, or Critical) that closely represents your opinion. Please provide justification or additional comments for your opinion, if applicable. Refer to the SMS Program Cost Estimation Tool to answer these questions.

23. Leadership roles as tools for implementing a safety management system program.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____

    ____

24. Understanding data resources and related costs for industry best practice tools such as Flight Operations Quality Assurance, Voluntary Disclosure Reporting Programs (VDRP), and Maintenance Error Decision Aid (MEDA) prior to implementing a safety management system program.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____

    ____

25. Project Planning Schedule.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

Justification or comments

____
____

26. Understanding employee resource costs prior to implementing a safety management system program.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____
    ____

27. Standards for Training.

    __ Not important
    __ Somewhat important
    __ Very important
    __ Critical

    Justification or comments

    ____
    ____

As a result of the responses in Round 1, the following questions are introduced in Round 2.

28. Why are the benefits of safety programs difficult to analyze and what are the barriers to provide a business case for safety programs for decision makers?

    ____
    ____

These next five questions are related to employee resources, specifically SMS training. In the literature related to accidents and incidents, one of the many casual factors reported was employee training. The ICAO SMS model requires an organization to maintain records for training and allows the organization to define the duration (time) each employee should receive related to SMS programs. The ICAO SMS Gantt chart (Work Breakdown Structure) includes suggestions for schedules (days) to account for SMS training. Standards related to the amount of time (duration) each employee should receive for SMS training could be a significant financial impact to an organization and is knowledge that a decision maker would be interested in prior to SMS implementation. Please provide your opinions of what minimum standard(s) for each phase of an SMS Implementation Plan, in the context of labor hours, is appropriate for SMS cost estimation modeling.

29. In your opinion, what minimum standard (hours) for *Indoctrination/initial on SMS, human factors and organizations* should an employee receive during Phase 1, Planning SMS Implementation? How would this standard affect program costs?

30. In your opinion, what minimum standard (hours) and cost impact of *Initial (general safety) training* should an employee receive during Phase 1, Planning SMS Implementation? How would this standard affect program costs?

31. In your opinion, what minimum standard (hours) and cost impact for *Training on SMS/risk management on reactive processes* should an employee receive during Phase 2, Reactive Safety Management Processes? How would this standard affect program costs?

32. In your opinion, what minimum standard (hours) and cost impact for *Training on SMS/system risk management on proactive and predictive processes* should an employee receive during Phase 3, Proactive and Predictive Safety Management Processes? How would this standard affect program costs?

33. In your opinion, what minimum standard (hours) and cost impact for *Training relevant to operational safety assurance* should an employee receive during Phase 4, Operational Safety Assurance? How would this standard affect program costs?

The last open-ended question gives you an opportunity to suggest new questions or modify any existing questions for the study.

35. What new questions or modifications of existing questions for this study would you recommend?

Appendix O:

SMS Cost Estimation Tool

A SMS Cost Estimation Tool was provided to each panelist in Round 2 to stimulate group thinking and new contributions. Data from the ICAO SMS model in the form of 102 work tasks was transcribed to a Microsoft Excel spreadsheet to create a SMS cost estimating tool. Specific data transcribed included the SMS phase and task name and estimated duration (days). Estimated duration columns A through E include corrections for mathematical errors. Adapted from "Safety management manual (SMM)" by International Civil Aviation Organization, 2009, (Doc 9859), 2nd edition, p. 10-APP 2-11. Copyright 2009 by International Civil Aviation Organization. Adapted with permission (see Appendix A).

Safety Management System Cost Estimation Tool

(Corrected for mathematical errors)

Cost Estimate for Phases 1 thru 4

SMS Phase and Task Name	Estimated Duration (Days)						ICAO Model Error	Estimated Duration (Hours)	Est Cost per labor Hour	Total Estimated Cost	Cost per Phase	SMS Trng Hours
Document	9859 Est	Corrections						See Note 1				
	↓	A	B	C	D	E						
Phase 1- Planning SMS Implementation	**157**						Yes				$130,176	
Management Commitment	**81**						Yes					
Accountable Executive and SMS Planning Group	**6**			**6**								
Identify the Accountable Executive	1				1			8.0	$48.00	$384		
Select person/planning group for SMS implementation plan	5				5			40.0	$48.00	$1,920		
System description and gap analysis	**35**			**35**								
Perform system description	15				15			120.0	$48.00	$5,760		
Perform gap analysis	20				20			160.0	$48.00	$7,680		
Safety policy and objectives	**12**						Yes					
Develop safety policy	5				5			40.0	$48.00	$1,920		
Safety policy signed by accountable executive	0				0			0.0	$48.00	$0		
Develop safety objectives for the SMS	5				5			40.0	$48.00	$1,920		
Safety objectives for the SMS established	2				2			16.0	$48.00	$768		
Establish SMS requirements for sub contractors	5				5			40.0	$48.00	$1,920		
Safety accountables and appointment of key safety personnel	**35**			**35**								
Develop SMS organizational structure	10				10			80.0	$48.00	$3,840		
Establish the Safety Service Office (SSO)	3				3			24.0	$48.00	$1,152		
Select Safety Manager	10				10			80.0	$48.00	$3,840		
Establish Safety Review Board (SRB)	3				3			24.0	$48.00	$1,152		
Establish Safety Action Groups (SAGs)	7				7			56.0	$48.00	$2,686		
Lines of safety accountability established	2				2			16.0	$48.00	$768		
SMS organizational structure in place	0				0			0.0	$48.00	$0		
Coordination of the emergency response planning (ERP)	**46**		**46**									
Internal coordination	**20**			**20**								
Review of ERP delegation of authority and emergency responsibilities	5				5			[illegible]	$48.00	$1,920		
Develop coordination procedures for key personnel	15				15			120.0	$48.00	$5,760		
External coordination	**26**			**26**								
Identify external entities with interaction during emergencies	5				5			40.0	$48.00	$1,920		
Access and assessment of their ERP	20				20			160.0	$48.00	$7,680		
Establish coordination between different ERPs	1				1			8.0	$48.00	$384		
SMS Documentation	**105**						Yes					
SMS Implementation Plan	**65**			**65**								
Develop SMS implementation plan draft proposal	40				40			320.0	$48.00	$15,360		
Identify potential challenges in the SMS implementation plan	7				7			56.0	$48.00	$2,688		
Develop provisions to address identified challenges	8				8			64.0	$48.00	$3,072		
Draft budget for SMS implementation	5				5			40.0	$48.00	$1,920		
Initial budget for SMS implementation approved	5				5			40.0	$48.00	$1,920		
SMS implementation plan approved	0				0			0.0	$48.00	$0		
Safety Management System Manual (SMSM)	**40**			**40**								
Develop draft SMSM	40				40			320.0	$48.00	$15,360		
Initial draft of SMSM published	0				0			0.0	$48.00	$0		

Created by N. Duncan

Appendix P:

Examples of Air Transportation Labor Categories and Wages

Examples of data available from the U.S. Bureau of Labor Statistics related to the aviation industry that could be included in a decision support system for SMS cost estimation.

Table P1

Examples of Labor Categories and Wages- Scheduled Air Transportation

Labor category[a]	Standard occupational classification (SOC) Code[a]	Mean hourly wage[a]	Annual mean wage[a]	Average benefit rate[b] (percent)	Benefit cost per hour[c]	Mean hourly wage + benefits[d]
Aerospace engineer	17-2011	$43.31	$90,080	25	$10.83	$54.14
Aircraft mechanic and service technician	49-3011	$27.50	$57,070	25	$6.88	$34.38
Avionics technician	49-2091	$27.50	$57,210	25	$6.88	$34.38
Chief executive	11-1011	$81.69	$169,920	25	$20.42	$102.11
Computer systems analyst	15-1121	$38.59	$80,260	25	$9.65	$48.24
Engineers, all other	17-2199	$39.16	$81,450	25	$9.79	$48.95
First-line supervisor	49-1011	$33.31	$60,290	25	$8.33	$41.64
Manager, all other[e]	11-9199	$44.88	$93,350	25	$11.22	$56.10
Manager, computer and information systems	11-3021	$60.15	$125,110	25	$15.04	$75.19
Manager, general and operations	11-1021	$56.82	$118,180	25	$14.21	$71.03
Manager, training and development	11-3131	$47.46	$98,720	25	$11.87	$59.33
Helper- installation, maintenance, and repair worker	49-9098	$16.01	$33,290	25	$4.00	$20.01
Occupational, health & safety specialist[e]	29-9011	$35.88	$74,630	25	$8.97	$44.85
Pilot, copilot, flight engineer[f]	53-2011	$62.33[g]	$119,180	25	$15.58	$77.92
Secretaries and administrative assistants	43-6014	$16.69	$34,710	25	$4.17	$20.86
Technical writer	27-3042	$31.00	$64,470	25	$7.75	$38.75

[a]Examples of labor categories and mean hourly wages for NAICS code 481100 for scheduled air transportation. Adapted from "May 2011 National industry- Specific occupational employment and wage estimates: NAICS 481100- Scheduled air transportation, U.S. Bureau of Labor Statistics." [b]The average benefit rate of 25% was used to calculate the mean hourly wage plus benefits. [c]Benefit cost per hour was calculated by multiplying the mean hourly wage by 25%. [d]The mean hourly wage plus benefits was calculated by adding the mean hourly wage plus the benefit cost per hour.

[e]A Standard Occupational Classification (SOC) code was not available for an Aviation Safety Manager. However, data for an occupational, health, and safety specialist (SOC code 29-9011) was available. [f]The wage data reported by the BLS for some occupations that do not generally work year-round, full time, are reported either as hourly wages or annual salaries depending on how they are typically paid. [g]The hourly wage was calculated by dividing the annual salary by a standard of 1912 labor hours per year (see Appendix Q). The 1912 labors hours per year is equivalent to an employee working eight hours a day, five days a week with paid leave for 11 federal holidays, 40 hours per year vacation, and 40 hours per year sick leave.

Table P2

Examples of Labor Categories and Wages- Non-scheduled Air Transportation

Labor category[a]	Standard occupational classification (SOC) Code[a]	Mean hourly wage[a]	Annual mean wage[a]	Average benefit rate[b] (percent)	Benefit cost per hour[c]	Mean hourly wage + benefits[d]
Aerospace engineer	17-2011	$42.69	$88,800	25	$10.67	$53.36
Aircraft mechanic and service technician	49-3011	$26.51	$55,150	25	$6.63	$33.14
Avionics technician	49-2091	$25.14	$53,740	25	$6.46	$32.30
Chief executive	11-1011	$89.10	$185,320	25	$22.28	$111.38
Computer support specialist	15-1150	$23.20	$48,260	25	$5.80	$29.00
First-line supervisor	49-1011	$36.16	$75,220	25	$9.04	$45.20
Manager, all other[e]	11-9199	$55.82	$116,110	25	$13.96	$69.78
Manager, computer and information systems	11-3021	$46.24	$96,180	25	$15.04	$75.19
Manager, general and operations	11-1021	$53.29	$110,840	25	$13.32	$66.61
Helper- installation, maintenance, and repair worker	49-9098	$17.25	$35,870	25	$4.31	$21.56
Pilot, copilot, flight engineer[f]	53-2011	$47.32[g]	$90,480[a]	25	$11.83	$59.15
Secretaries and administrative assistants	43-6014	$17.46	$36,310	25	$4.37	$21.83

[a]Examples of labor categories and mean hourly wages for NAICS code 481200 for non-scheduled air transportation. Adapted from "May 2011 National industry- Specific occupational employment and wage estimates: NAICS 481200- Scheduled air transportation, U.S. Bureau of Labor Statistics." [b]The average benefit rate of 25% was used to calculate the mean hourly wage plus benefits. [c]Benefit cost per hour was calculated by multiplying the mean hourly wage by 25%. [d]The mean hourly wage plus benefits was calculated by adding the mean hourly wage plus the benefit cost per hour. [e]A Standard Occupational Classification (SOC) code was not available for an Aviation Safety Manager. [f]The wage data reported by the BLS for some occupations that do not generally work year-round, full time, are reported either as hourly wages or annual

salaries depending on how they are typically paid. [g]The hourly wage was calculated by dividing the annual salary by a standard of 1912 labor hours per year. The 1912 labors hours per year was equivalent to an employee working eight hours a day, five days a week with paid leave for 11 federal holidays, 40 hours per year vacation, and 40 hours per year sick leave.

Appendix Q:

Estimated Cost of Training per Hour

Examples of costs related to SMS training was created in Microsoft Excel software that could be included in decision support system for SMS cost estimation. Panelists identified information decision makers would be interested in for SMS cost estimation modeling. The data was the result of panelist responses to Round 2 Questions 29-33 and adapted to understand estimated costs.

Table Q1

Estimated Cost of Training per Hour

Estimated Cost of Training per Hour

Note 1	# of Emp	Duration of Training (Hours) and Cost									
$48.00	(Note 2)	1	2	3	4	8	16	24	32	40	80
Small & Medium Org	10	**$480**	**$960**	**$1,440**	**$1,920**	**$3,840**	**$7,680**	**$11,520**	**$15,360**	**$19,200**	$1,843,200
	50	**$2,400**	**$4,800**	**$7,200**	**$9,600**	**$19,200**	$38,400	$57,600	$76,800	$96,000	$9,216,000
	100	**$4,800**	**$9,600**	**$14,400**	**$19,200**	$38,400	$76,800	$115,200	$153,600	$192,000	$18,432,000
	150	**$7,200**	**$14,400**	**$21,600**	**$28,800**	$57,600	$115,200	$172,800	$230,400	$288,000	$27,648,000
	200	**$9,600**	**$19,200**	**$28,800**	$38,400	$76,800	$153,600	$230,400	$307,200	$384,000	$36,864,000
	250	**$12,000**	**$24,000**	$36,000	$48,000	$96,000	$192,000	$288,000	$384,000	$480,000	$46,080,000
	500	**$24,000**	$48,000	$72,000	$96,000	$192,000	$384,000	$576,000	$768,000	$960,000	$92,160,000
	750	$36,000	$72,000	$108,000	$144,000	$288,000	$576,000	$864,000	$1,152,000	$1,440,000	$138,240,000
	1000	$48,000	$96,000	$144,000	$192,000	$384,000	$768,000	$1,152,000	$1,536,000	$1,920,000	$184,320,000
	1250	$60,000	$120,000	$180,000	$240,000	$480,000	$960,000	$1,440,000	$1,920,000	$2,400,000	$230,400,000
	1500	$72,000	$144,000	$216,000	$288,000	$576,000	$1,152,000	$1,728,000	$2,304,000	$2,880,000	$276,480,000
Large Organization	2000	$96,000	$192,000	$288,000	$384,000	$768,000	$1,536,000	$2,304,000	$3,072,000	$3,840,000	$368,640,000
	3000	$144,000	$288,000	$432,000	$576,000	$1,152,000	$2,304,000	$3,456,000	$4,608,000	$5,760,000	$552,960,000
	4000	$192,000	$384,000	$576,000	$768,000	$1,536,000	$3,072,000	$4,608,000	$6,144,000	$7,680,000	$737,280,000
	5000	$240,000	$480,000	$720,000	$960,000	$1,920,000	$3,840,000	$5,760,000	$7,680,000	$9,600,000	$921,600,000
	6000	$288,000	$576,000	$864,000	$1,152,000	$2,304,000	$4,608,000	$6,912,000	$9,216,000	$11,520,000	$1,105,920,000
	7000	$336,000	$672,000	$1,008,000	$1,344,000	$2,688,000	$5,376,000	$8,064,000	$10,752,000	$13,440,000	$1,290,240,000
	8000	$384,000	$768,000	$1,152,000	$1,536,000	$3,072,000	$6,144,000	$9,216,000	$12,288,000	$15,360,000	$1,474,560,000

Note 1	# of Emp	Duration of Training (Hours) and Cost									
$48.00	(Note 2)	1	2	3	4	8	16	24	32	40	80
	9000	$432,000	$864,000	$1,296,000	$1,728,000	$3,456,000	$6,912,000	$10,368,000	$13,824,000	$17,280,000	$1,658,880,000
	10000	$480,000	$960,000	$1,440,000	$1,920,000	$3,840,000	$7,680,000	$11,520,000	$15,360,000	$19,200,000	$1,843,200,000
	20000	$960,000	$1,920,000	$2,880,000	$3,840,000	$7,680,000	$15,360,000	$23,040,000	$30,720,000	$38,400,000	$3,686,400,000
	30000	$1,440,000	$2,880,000	$4,320,000	$5,760,000	$11,520,000	$23,040,000	$34,560,000	$46,080,000	$57,600,000	$5,529,600,000

Note 1. Estimated Cost of Training per Hour. The data represents the financial impact of SMS training for employees that could be employed by small, medium, and large aviation entities. The $48 per hour was influenced by the cost estimation noted in the FAA NPRM (2010d).

Note 2. Number of employees. The range of number employees was influenced by the panelist's responses which included discussion of training, size, and scope of aviation organization similar to the FAA NPRM (2010c) for small, medium, and large aviation entities.

Note 3. Duration of Training (Hours) and Cost. The range of 1 to 80 hours for the duration of training was the opinion of the Delphi panelists. The data is a result of multiplying the number of employees by an average labor cost of $48 per hour and the number of training hours.

Note 4. A total of 90 days (720 labor hours) for training is included in the ICAO SMS model and identified in boldface font.

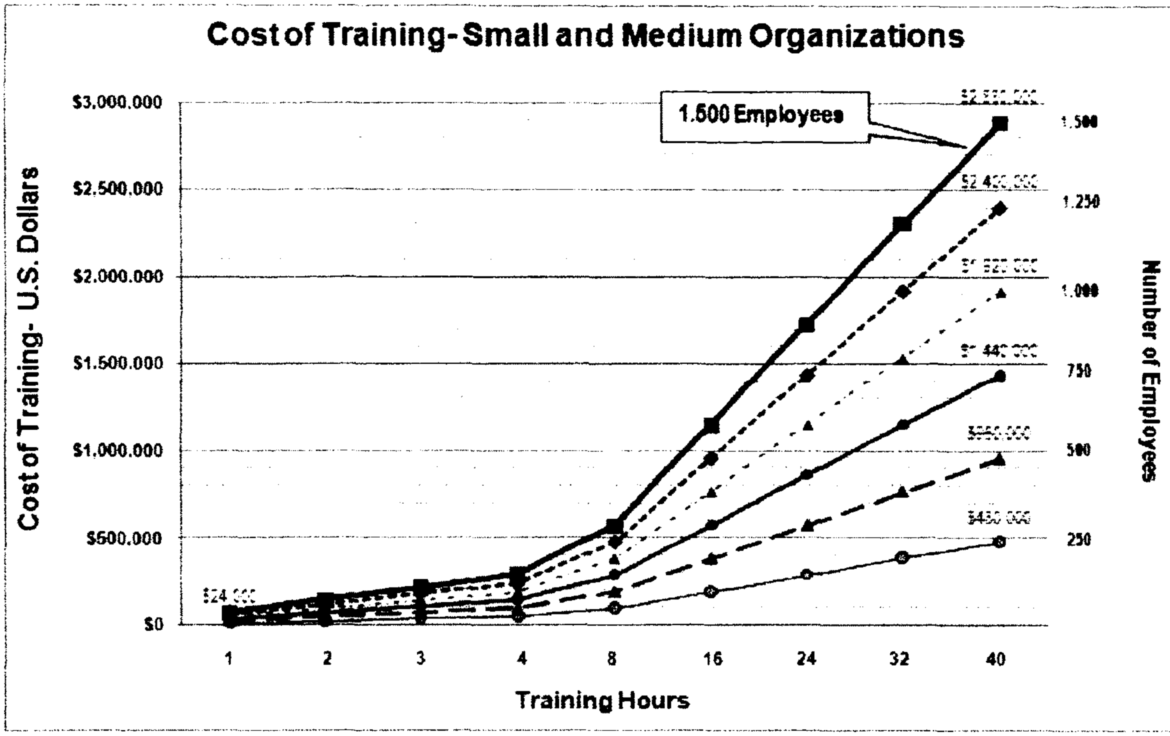

Figure Q1. Estimated Cost of Training- Small and Medium Organizations. In Figure Q1, graphical form of data from Table Q1 for the range of 250 to 1500 employees. The figure was created by N. Duncan using Microsoft Excel software.

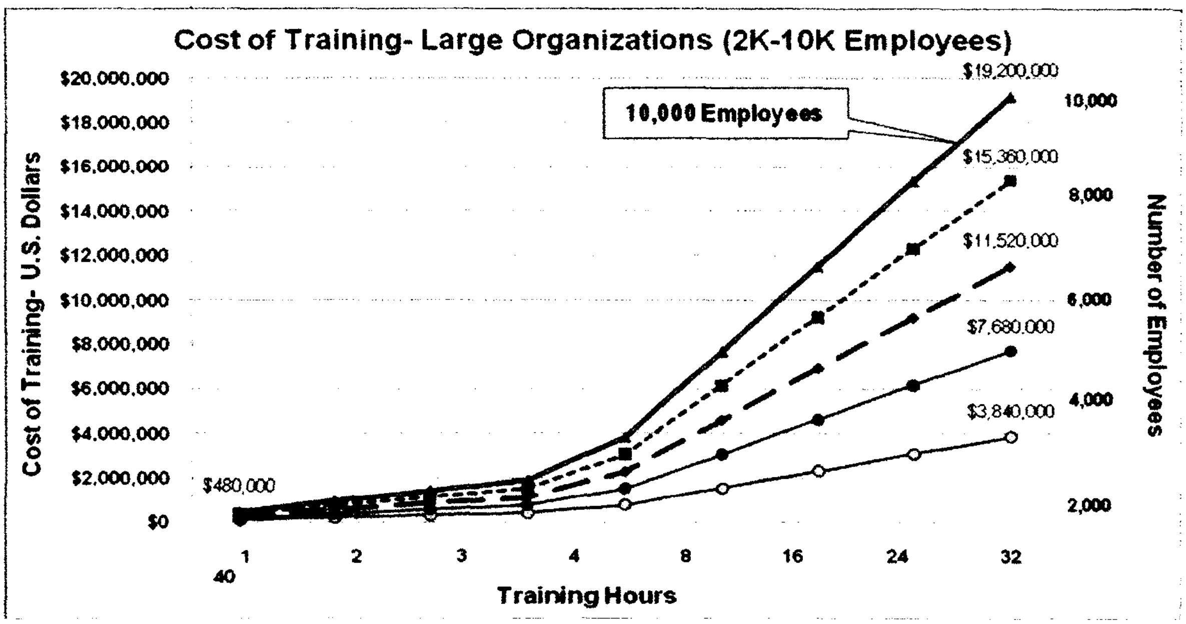

Figure Q2. Estimated Cost of Training- Large Organizations (2K-10K Employees). In Figure Q2, graphical form of cost data from Table Q1 for the range of 2,000 to 10,000 employees. The figure was created by N. Duncan using Microsoft Excel software.

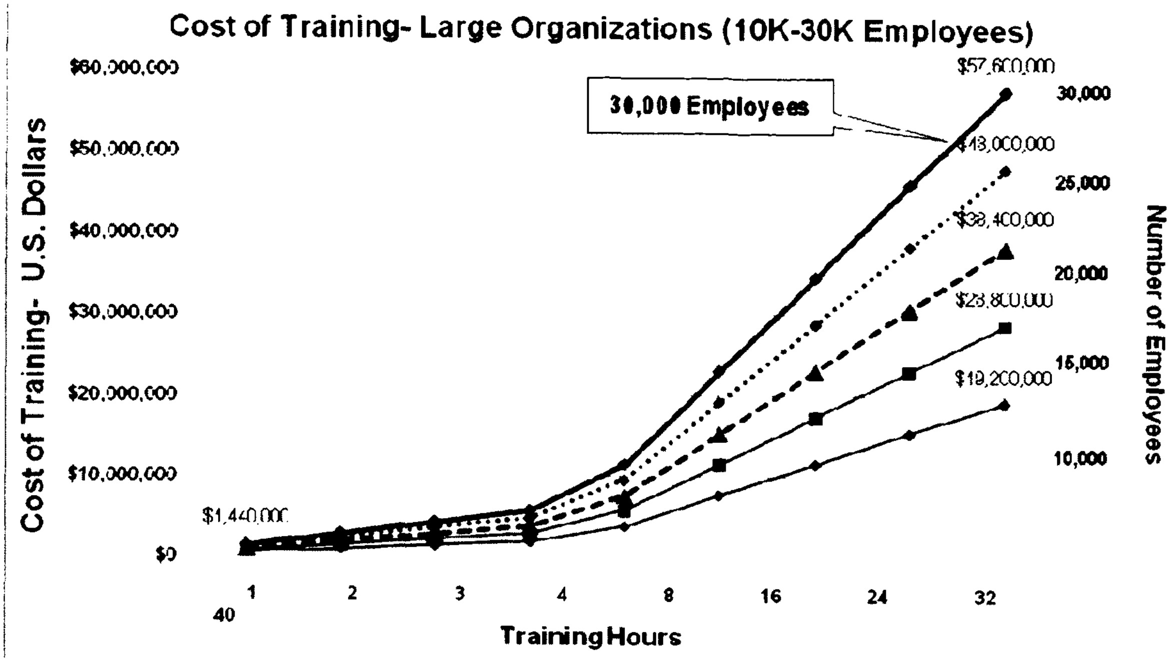

Figure Q3. Estimated Cost of Training- Large Organizations (10K-30K Employees). In Figure Q3, graphical form of data from Table Q1 for the range of 10,000 to 30,000 employees. The figure was created by N. Duncan using Microsoft Excel software.

Appendix R

Round 3 Questionnaire

A DELPHI STUDY OF DECISION SUPPORT SYSTEMS FOR AVIATION SAFETY MANAGEMENT PROGRAM COST ESTIMATION
DELPHI ROUND THREE QUESTIONNAIRE

The questions for Round 3 were built on the foundation of the responses in Round 2. Please answer the following questions related to SMS **decision support systems for SMS cost estimation**. Decision support system models include the documents, knowledge, and data available to help managers solve problems. Please answer each question assuming an organization has **not implemented** any elements of an SMS program and all items suggested in the ICAO SMS program model work breakdown structure **(WBS)** apply.

1. Please rank the importance of the following items for the development of a decision support system for **SMS cost estimation** with 1 being the most important, 2 being the next important, etc. Please add any additional items you believe are important for the development of a decision support system for SMS cost estimation.

   __ Cost Analysis

   __ Cost Benefit Analysis

   __ Financial Schedules (employee wages identified in Collective Bargaining Agreements, U.S. Bureau of Labor Statistics, company pay schedules, etc.)

   __ Regulations

   __ Scope of work (inclusion of FOQA, VDRP, MEDA, etc.)

   __ Size of an organization (number of employees requiring training)

   __ Work Breakdown Structure (identification of work scope)

   __ Other ______________________________

Please mark 'X', circle, bold, or highlight your choice (Strongly Agree, Agree, Neither Agree or Disagree, Disagree, or Strongly Disagree) that closely represents your opinion. Please provide justification or additional comments for your opinion.

2. The regulatory requirements are important in assessing the **scope** of an SMS program.

   __ Strongly Agree
   __ Agree
   __ Neither Agree nor Disagree
   __ Disagree
   __ Strongly Disagree

Justification or comments

____

____

3. A **cost analysis** should be conducted prior to implementing a safety program in order to understand expenses and demonstrate benefits.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

4. The WBS provides the scope of work necessary to accomplish **cost and schedule** estimations.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

5. A **cost benefit analysis** should be conducted prior to implementing a safety program in order to understand expenses and demonstrate benefits.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

6. The **cost benefits** of safety programs are difficult to analyze because it is a different way of doing business.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

7. The **cost benefits** of safety programs are difficult to analyze because benefits are subjective.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

8. In order to overcome barriers for making a business case for SMS programs, companies need to understand or try to model the costs of incident and accidents.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

9. In order to overcome barriers for making a business case for SMS programs, companies need to understand costs of undesired events and the predicted impact to the survival of the company.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

These next five statements are related to employee resources, specifically SMS training. In Round 3, an additional tool related to SMS training was created by the researcher to understand the training costs suggested in Round 2. Please refer to the tool titled ***SMS Cost Model- Estimated Cost of Training per Hour*** to answer the following questions. Please mark 'X', circle, bold, or highlight your choice (Strongly Agree, Agree, Neither Agree or Disagree, Disagree, or Strongly Disagree) that closely represents your opinion. Answer each statement assuming an organization has **not implemented** any elements of an SMS program.

10. The training standards a decision maker selects for Phase 1, Planning SMS Implementation, specifically, for *Indoctrination/initial on SMS, human factors and organizations* would affect program costs.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

11. The training standards a decision maker selects for Phase 1, Planning SMS Implementation, specifically, for *Initial (general safety) training* would affect program costs.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

12. The training standards a decision maker selects for Phase 2, Reactive Safety Management Processes, specifically, for *Training on SMS/risk management on reactive processes* would affect program costs.

__ Strongly Agree
__ Agree

__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

13. The training standards a decision maker selects for Phase 3, Proactive and Predictive Safety Management Processes, specifically, for *Training on SMS/system risk management on proactive and predictive processes* would affect program costs.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

14. The training standards a decision maker selects for Phase 4, Operational Safety Assurance, specifically, for *Training relevant to operational safety assurance* would affect program costs.

__ Strongly Agree
__ Agree
__ Neither Agree nor Disagree
__ Disagree
__ Strongly Disagree

Justification or comments

____

____

Appendix S:

Researcher E-mail Script for Participant Acknowledgement

Date:

Subject: Delphi Study Participant Acknowledgement Consent and Round 3 Feedback

To: (Delphi Panel Participant)

Hello (Panelist Name),

Thank you contributing your time to participate in the *Delphi Study of Decision Support Systems for Aviation Safety Management Program Cost Estimation.* The feedback for Round 3 is attached. As part of this study, you may be acknowledged for your contribution. However, your employment affiliation will not be included in the acknowledgement. I would like your consent to acknowledge your participation if the final research report. The final research report will be in the form of a published dissertation. Please let me know if you consent to formal acknowledgment by responding via e-mail.

Thank you again for your help with this study.

Sincerely,
Nina Duncan
Cell: XXX-XXX-XXXX