Economic Modeling to Improve Estimates of the Benefits of Safety Management Systems

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Abstract

Safety Management Systems (SMS) in aviation have the potential to minimize costs, protect profits, and increase shareholder value. However, a gap exists in SMS research between the acknowledged safety benefits of SMS and the identified economic benefits. In the current competitive marketplace, SMS will need to demonstrate economic viability through modeling before industry leaders are likely to adopt a voluntary process. This paper reviews the literature related to a variety of possible economic models applicable to measuring the benefits of the application and implementation of SMS in aviation organizations. While the ultimate goal is to increase safety, the utilization of a model chosen based on the needs of the organization, could encourage voluntary adoption of SMS before regulations make it mandatory. The model will better inform the adopters of SMS of benefits and the processes themselves so that SMS does not degrade into a focus on following process steps rather than improving safety. Using good models that estimate the benefits of SMS would facilitate decision making as well as support the implementation of SMS.

Introduction

Incidents, accidents, and poor product and service quality due to safety challenges are part of the quantifiable costs of doing business. However, Roth (2004) questioned whether or not these are a required cost of doing business. Economist Milton Friedman maintained that the business of business is business (Davis, 2005). Combining Friedman's statement with Drucker's (1986) principle that the minimization of loss is the charge of business, are the costs associated with incidents, accidents and poor quality really a required cost of business? Cox and Flouris (2011) presented a simple spreadsheet tool to enable aviation safety officers to present their safety proposals with return on investment (ROI) measures in the language of Chief Financial Officers (CFO). As safety increasingly becomes a cost liability for businesses, it needs to be viewed as a value-producing center rather than a regulatory compliance center (Rosenkrans, 2011). Economic modeling of SMS implementation could increase the likelihood that organizations aggressively embrace SMS principles rather than just follow additional steps required by the regulators.

While not restricted solely to the aviation industry, studies show that 85-95% of accidents are caused by what employers or employees choose to do (Adebiyi, Charles-Owaba, & Waheed, 2007). It is clear from the Federal Aviation Administration (FAA) and International Civil Aviation Organization (ICAO), SMS is quickly becoming a requirement in the aviation industry. Both the FAA Advisory Circular 120-92a and ICAO's Safety Management Manual provides guidance for the implementation of SMS from a regulatory frame of reference (FAA, 2010a; ICAO, 2009). The four components

or pillars of SMS are policy, risk management, safety assurance, and safety promotion (FAA, 2010a; ICAO, 2009; Stolzer, Halford, & Goglia, 2008). SMS is the continual process of formalized assessment of processes intended to identify issues prior to crisis, fix them and assuring they remain fixed in an effort to continually improve the safety of the aviation system. If accident costs can be mitigated or controlled through the implementation of Safety Management Systems (SMS), then the business of business would oblige leaders of these organizations to put a system into place that minimizes the cost of doing business and protects profits and increases shareholder value. Leaders would have a powerful economic incentive to implement SMS. The cost of employing SMS would be viewed as a source of profit management rather than a regulatory burden, gimmick, or fad program for those organizations that have not been early adopters of SMS (Lenz, 2012).

While the costs of implementation of an SMS can be transparent, the benefits of an SMS are not as readily available and quantifiable, nor is there one accepted approach or standard in the industry. An apparent gap exists in the SMS discipline where sound economic models can be applied to incentivize industry leaders to adopt SMS as a core operation within their organizations based on generally accepted economic valuation of the output (Stolzer, Halford, & Goglia, 2008). Unfortunately, in the current competitive marketplace where every cost is scrutinized and many times safety isn't a problem until the accident happens to your company, safety officers need to demonstrate economic viability of safety improvements through modeling before industry leaders are likely to adopt a voluntary process that increases costs (Stolzer, Halford, & Goglia, 2008). Esquer-Peralta, Velaquez, and Munguia (2008) found that 43% of their surveyed sustainability management system experts declared that having a clear understanding of the long-term economic benefits for the company is an important incentive for their implementation of a management system. In order to better illustrate the economic benefits of the application and implementation of SMS in aviation organizations, this paper reviews the literature related to a variety of possible economic models.

Why Economic Principles?

In the late 20th century, the discipline of economics evolved to include a branch that studied risk-based modeling including probabilities of events over time rather than price-based modeling that simply weighed the costs against direct benefits. The study of risk views variations in values over time as more important than actual experienced price or cost. Using risk-return tradeoffs, better informed decisions can be made. SMS essentially strives to make informed decisions on risk-return trade-offs. Under SMS, risk is reduced to an acceptable level by engineering out presented hazards. By removing or significantly reducing the risk, costs are minimized and expenditures for adverse incidents can be more closely controlled. Financially, residual risk can be transferred to a third party through insurance contracts for a premium (Roth, 2004). Numerous studies exist and conclude that the financial performance of SMS adopters outperforms non-adopters (Bottani, Monica, & Vignali, 2009). From these studies one can implicitly conclude that adoption of SMS is positively financially rewarded. Further, by using economic modeling to explicitly quantify benefits, businesses could be better

129

incentivized to engage in processes under SMS to do the business of business. Moreover, as previously mentioned, the business of business is minimizing losses.

Literature Review of Possible Economic Models

Various measurement models of the benefits of safety programs have been employed within the aviation industry and in other industries. Each modeling framework has pros and cons depending on the specific situation. However, choosing the appropriate evaluation method should help focus the SMS effort from regulatory/compulsory adoption to voluntary industry adoption based on positive financial projections.

Accounting Approach

Friend (2011) and Skydel (2011) established a reactionary but basic direct accounting approach to estimate total business costs without SMS intervention. The direct accounting approach calculated the sum of possible losses (actual estimate of costs multiplied by the probability of occurrence) of the various activities under SMS using past recorded data of the organization or industry averages. They allowed that the possible loss calculation may also incorporate trend analysis and rates of growth of certain costs and incidents. This is a basic direct approach of estimating losses. However, it is backwards thinking or reactive in nature. It does not account for the constantly changing operations of the industry. It also does not include statistical concepts such as variability in probabilities of costs or risk used.

Some studies used cost estimates gathered by questionnaires from departments within an organization (Phelps, 1999). However, the cost estimates could be suboptimal as employees could inflate their estimates in an effort to increase their standing or importance in the organization. With those considerations in mind, using this method, objective estimates of costs should be used if the accounting approach is employed.

Time-Driven Activity-Based Costing

Time-driven activity-based costing (TABC) is a proprietary financial methodology developed by John Cox, CEO of Safety Operating Systems, and Triant Flouris, professor and Dean of Academic Affairs at Hellenic American University. The TABC aims to intentionally estimate an airline's organizational safety costs as an integrated organization using value-chain management. The accounting worksheet aims to identify or highlight variable and fixed costs for customization by safety officers who want to prototype their business. The developers claimed their model provides an accurate prediction of bottom line cost savings for safety proposals but no empirical justification was presented (Rosenkrans, 2011; Safety Operating Systems, 2012).

Federal Aviation Administration's Return on Investment Simulator

The Federal Aviation Administration (FAA) also developed an accounting worksheet and Microsoft PowerPoint training course designed to assist safety managers in communicating with their respective financial specialists about strategic safety decisions.

130

The worksheet estimates benefits of expected expended costs and frequencies, and probability of safety events over six quarters. Each calculated ROI presents before-safety and after-safety measure values. The higher the ROI, the more money the airline would make from the safety investment (Rosenkrans, 2011). While basic and direct, the simulator can be manipulated with incorrect input data. The adage of garbage in, garbage out leads any model to calculate inaccurate estimates. However, the simplicity of the model would be attractive to self-directed safety officers intending to convey the benefits of investment in SMS in the organization as well as any perceived endorsement by a regulatory body.

Cost-Benefit Analysis using Historical Data

The FAA's initial regulatory evaluation estimated the benefits of implementing SMS on Part 121 operators using a cost-benefit approach that can be scaled down to a single organization. The FAA determined that in the past ten years, 172 accidents could have been prevented in whole or in part with SMS in place. The FAA used actual economic value from these accidents and then took 50% of the actual losses for 167 of the accidents and 5% of the remaining 5 more serious accidents that resulted in other policies and procedures changes. The FAA based their 50% reduction value from reductions in losses due to safety as a result of SMS implementation in non-aviation organizations. Organizations adopting Voluntary Protection Programs (VPP) typically experience a 10-20% reduction in losses. However, the FAA reasoned the more formalized and intensive nature of SMS warrants a higher expectation of reductions in losses due to safety issues. The FAA also delayed benefit accumulations until the third year after implementation (Federal Aviation Administration, 2010b). This approach is wholly reactive thinking as it uses past experience as a fair representation of future expectations in a constantly evolving industry.

Cost-optimization Algorithms Combined with Probable Risk

Cost optimization algorithms can be employed in a simulation including a budget constraint. Similar to the cause and effect diagram presented by Stolzer, Halford, and Goglia (2008), a fault tree analysis is combined with expectations of primary failure probabilities and cost parameters at the lowest level of the hierarchy of events in the fault tree. Minimizing lower level primary failures will minimize top level critical failures. Proactively, engineering solutions to predictive primary failures could be employed to lower the probability of failure to minimal accepted levels or limits. The entire system is subject to a budget constraint. Businesses can invest an enormous amount of resources in order to increase savings. By employing a cost sensitivity priority ranking of failures, this simulation informs management which failures are most costly, and which low level failures must be prevented in order to lower the probability of top level critical failures and the benefits of proactive SMS activities. Management could forecast where they would experience the biggest minimization of the failure cost and thus a lowering of the probability of a top level critical failure (Ben-Yair, 2004). These minimizing of cost failures are a proxy for the benefits of implementing SMS within the organization. A major drawback of this analysis is that it omits the human factor in quality escapes that

131

are a critical piece of managing safety assurance that is different from a traditional quality assurance framework (Stolzer, 2012).

Analytical Hierarchical Process

Analytical hierarchical process (AHP) is not necessarily an economic model, but can be applied to economics as a technique that breaks down a complex process into sub-processes that include human decisions, and assigns numerical values that represent priority, weighting, or significance levels of each sub-process in the overall process. AHP as used in VPP can be extended as a rank-ordered cost-benefit quantitative measure of the inclusion of SMS to an organization which can then inform policy and priorities. Within this process, each element of the SMS is detailed into a pair of event options. One such element within SMS could be a hypothetical checklist that could include either checking air pressure on airplane's tires at each gate location, or alternatively, at the beginning of each day of service. Once all the elements in a process are detailed, an analyst must then prioritize the elements in order of desirability or importance. Each pair is then valued, once for the costs required to apply SMS principles to the element and once for the perceived benefit of application of SMS principles to the element. The element values can then be transformed into a benefit to cost ratio that was created using expert judgments and experience (Jervis & Collins, 2001).

This process informs SMS in two ways. First, the estimate of benefits is determined by those who would be involved in the implementation of SMS. Hence, the importance of SMS buy-in, which is a difficult intangible cost and benefit to estimate, by those who would be affected are built into the analysis of proposed benefits of elements. Second, with budget constraints, the ranking of the benefit to cost ratios can inform management which elements of the SMS will have the maximum impact and thus be considered the easiest achievable targets that yield the greatest benefits. The resulting estimates of benefits would not necessarily result in an aggregate benefit of implementing SMS within an organization. The real illumination of benefits would be at the granular level of each process that was evaluated. A drawback of this method is that it would be involved and time consuming to tabulate the numerical values at each sub-process.

Simulation Model Using System Dynamics and Data Mining

The models presented thus far omit two important factors, organizational and management factors. The hierarchical decision making processes described above used as an indicator of savings from safety improvements assume accidents result from a chain of events or are limited to component failures. A simulation employing a system dynamics approach incorporates more complex relationships between the four pillars of SMS: policy, safety risk management, safety assurance, and safety promotion. System dynamics models would incorporate human decision making and system drift over time towards an accident (Charles-Owaba & Adebiyi, 2006). Possibly more important to preventing accidents is identifying negative organizational behavior while submitting to cost-efficiencies in aggressive competitive environments (Ives, 2002; Rasmussen, 1997). Combining historical data of accidents that include management failures with systems

132

dynamics models can yield estimates capturing both the human factors plus component failure values.

Applications of systems dynamics models are typically found in manufacturing industries. Since the FAA uses benefit gain estimates from adapting SMS from the manufacturing industry to evaluation of Part 121 operators, system dynamics estimates from manufacturing industries could also be transferrable (FAA, 2010b). Strengthening this model to evaluate the benefits of an SMS should include the incorporation of the human decision making factor or human-machine interaction that is often present in aviation accidents (Whealan George, 2012).

Using Forrester's (1973) conventional simulation model synthesis methodology, Charles-Owaba and Adebiyi (2006) used modeling to evaluate safety at a manufacturing bottling company. The simulation model was built on a pre-safety program period in the manufacturing company and then run for predictions and evaluated against a post-safety program implementation. Some assumptions were unrealistic, such as zero inflation and a stable government policy. Yet, the model still performed well and could assist the SMS planner to monitor and control SMS. Moreover, the model resulted in a good estimate of benefits of a safety implementation as there was no difference in the mean predicted benefit value and the actual benefit value.

One caution should be noted, this is not a perfect translation of methodology from one industry to another. Occupational safety is different than catastrophic aircraft accident risk where the aircraft accident risk has a low probability of occurrence making it particularly difficult to predict benefit values. Occupational safety accidents have, in general, a higher probability of occurrence and therefore predicting benefit values is less difficult.

Baldrige Performance Excellence Model

Recall that the very definition of SMS is a risk management system built on Quality management system (QMS) principles. The QMS principles are the policies and procedures used to improve the business processes that will result in improved organizational performance (Stolzer, Halford, & Goglia, 2008). The Malcom Baldrige National Quality Improvement Act of 1987 sought to enhance U.S. business competitiveness by improving quality and productivity. The Baldrige performance excellence model (BPEM) estimates the net social value of improved quality performance. Benefits of safety improvements are beyond financial terms and include the value society receives by an improved, sustainable performing industry that has public confidence (Link & Scott, 2011). If SMS is based on QMS principles, then estimating benefits using the BPEM would be appropriate. Researchers studied what the private sector would have to invest to achieve the same level of benefits provided through the publicly funded BPEM.

Benefits for organizations implementing a performance excellence program using the Baldrige criteria exceeded the quantifiable gains and losses on an organization's income statement. They included three categories of social benefits: gains to consumers from

133

higher quality products, value created for the organization from the publicly funded Baldrige Performance Excellence Program, and macroeconomic gains by saving scarce resources. In 2010, the most inclusive and conservative BPEM benefit to cost ratio estimated that the social benefits are 820-to-1 and representative of most industry sectors. This means there was an $820 dollar return on every $1 spent in QMS using Baldrige criteria for Baldrige award applicants. It is important to note, this measure is not specified for the organizational gain but the entire economy's impact (Link & Scott, 2011). While this is not an organizational bottom line estimate of benefits, it certainly makes the case for benefits of engagement in SMS using Baldrige Criteria that would result in cost advantages for the organization.

Contrarian View of Safety at Any Cost and Modeling Benefits

Vasign, Fleming, and Tacker (2008) seem to suggest that despite the various ways of measuring benefits, safety may have reached a long term economic equilibrium. The accident rate of commercial aircraft accidents per million departures in the United States decreased significantly from 1949 into the mid-1980s, stagnated, and then decreased further through 2009 (Moses & Savage, 1990; NTSB, 2011). Conceivably, accidents could be reduced even further with SMS, but the costs of doing so would be higher than the benefits received and intangibles become difficult to measure. These intangibles could include passenger reaction, labor reaction, stock market effects, liability risks, and government enforcement (Kaplinski & Levy, 2010). As an example, the FAA did not mandate child restraint seats on commercial airlines. With air travel and driving as substitutes, requiring families to purchase additional airline tickets increases the net number of fatalities as driving is more dangerous than flying and passengers would opt to drive (Coats, 2010).

In addition to questioning the cost-benefit of adopting SMS, Vasign, Fleming and Tacker (2008) remarked that these models may not be the best way to fairly evaluate the benefits of SMS. This statement is further justified as safety regulations are typically put into place without thorough economic consideration of unintended consequences despite regulatory impact assessments. Historically, some safety regulations are enacted due to potential threats in response to media-hyped passenger concerns that really do not affect safety. Others are just plain political processes. Even Stolzer, Halford, & Goglia (2008) noted the purpose of the 1995 Aviation Safety Summit was to improve safety and increase public confidence. Public confidence is not a core value of QMS and clouds the economic valuation models, but it is a reality of the industry and government. Vasign, Fleming, & Tacker (2008) cited the "Southwest rule" (p. 347) example or the regulation banning push-back until all passengers are seated. The authors state the rule was adopted because of political pressure from competitor airlines lobbying against Southwest's gate turn around and taxiing practices rather than a safety-inducing practice where financial benefits outweigh the costs. "It is probably true that, contrary to popular belief, aviation safety and security exceeds the levels that might be considered economically efficient" (Vasign et al., 2008, p. 347).

Robert Poole, head of the National Reason Foundation argued that measurement of the benefits of safety would be much more straightforward if regulations were privatized,

similar to what Lenz (2012) proposed in an effort to remove the unintended effects of the punitive nature of safety data reporting (Andrade, 1987). A privatized regulatory system includes private third parties and insurers that have a vested interest in aviation safety. These third parties would be interested only in measures that improve safety and would charge lower premiums for organizations that meet a specific threshold for safety and higher premiums for those organizations that take on higher risks. In an effort to minimize costs, organizations would adopt SMS as a core operational business practice. Private regulators would not be able to demand any corrections where problems may exist. The market would incentivize undue risk and the entire model would take on a purely economic paradigm instead of being influenced by political or media interests. In theory, the private regulator that publishes records could be fired if they do an inadequate job. This model is unlikely to be politically attractive any time soon given the financial industry's recent experience with private monitors like S&P or Moody's not properly examining and publishing data that reflected the true status of the banks, financial companies, and financial products that led to the subsequent collapse of 2008.

Discussion and Recommendations

It is clear from the FAA and International Civil Aviation Organization (ICAO;) SMS is quickly becoming a requirement in the aviation industry. Both the FAA Advisory Circular 120-92a and ICAO's Safety Management Manual provides guidance for the implementation of SMS from a regulatory frame of reference (FAA, 2010a; ICAO, 2009). Over time, perhaps clear financial benefits and resource savings will offer SMS greater acceptance by organizations as a beneficial proactive business practice instead of regulatory compliance. But, until that premise is widely accepted in the industry, commitments to safety as a core business operation will most likely be driven by regulatory requirements rather than financial rewards.

Regulations or government standards are often viewed as an unnecessary increase in an organization's costs (Charles-Owaba & Adebiyi, 2006). However, if an acceptable model for estimating the benefits of adopting and implementing SMS were developed, then some of the peripheral perception of unnecessary increased costs by those in the field, and the leaders of the organizations themselves, could be overcome. As mentioned before, the business of business is business and undertaking the best processes to run a profitable, sustainable business that is also in compliance with current regulations should be the main goal of top management of an organization. Using good models that estimate the benefits of SMS would facilitate decision making as well as support the implementation of SMS. This could also serve as part of the metrics of the assessment of SMS (Charles-Owaba & Adebiyi, 2006; Stolzer, Halford, & Goglia, 2008).

All the models presented have advantages and disadvantages and review of the relevant literature has not yielded specific guidance on what model would be considered best. Some smaller organizations may want to initially employ the simple cost accounting or historical cost-benefit model in order to estimate the benefits. The understanding needs to be that the models are limited to event-chain measures. Other more complex organizations should employ the systems dynamics models to capture the interaction of human actions with systems and the resultant organizational drift to best

135

estimate SMS's benefits. While the drawback to systems dynamics is that it is a complex model to run and certainly not a back-of-the-envelope or spreadsheet model, it incorporates the many human factors present in organizations utilizing both a historical and predictive perspective.

The functionality and user friendliness of any model may be the first criteria for selection of a model. The second criteria may be the model that speaks to the organization's management in their financial language. The FAA and the TABC - both commercial accounting models - intend to be user-friendly models that will deliver the positive, bottom-line message of a proactive SMS to Chief Executive Officers/Chief Financial Officers better and may be the best operational tool for estimating benefits in a competitive marketplace. The utilization of an economic model, whichever one is chosen based on the needs of the organization, would be a significant management tool to help reach the ultimate goal of improved safety. The model will better inform the adopters of SMS of benefits and the processes themselves so that SMS does not degrade into a focus on following process steps or managing a model rather than improving safety. Once organizations commit to using an economic model as part of their SMS implementation, they will need to decide which method of analysis is appropriate for their circumstances. The body of knowledge on this subject needs to be strengthened with a study that evaluates which model is the best for SMS estimations and deserves future research.

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139