A Case Study of Planned Adaptation in Aviation: The National Transportation Safety Board

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Abstract

This paper discusses the evolution of aviation safety in the United States with a focus on if the creation of the National Transportation Safety Board (NTSB) as an example of planned adaptation of regulatory policy and safety standards. The research suggests that the creation and resultant efforts of the NTSB contributed to the reduction of commercial airline accidents and fatalities by establishing a rigorous process for constant evaluation and updating of safety standards and technologies. Specific markers of planned adaptation in the aviation sector are identified which support the existence and operation of this model. These include the autonomy of the NTSB, a relevant and credible knowledge assessment process, and the capability of the NTSB to exert influence over the industry and regulatory process. Furthermore, unique aspects of the NTSB which potentially enable the effective application of planned adaptation are abstracted to contribute to the discussion of planned adaptation in regulation. Such aspects are found to include substantial influence through the leveraging of public interest, a mandated periodic knowledge assessment, and the capability to advocate for regulatory adaptation. Finally, challenges facing the continued operation of the planned adaptation model in US aviation are identified to include undue industry or FAA influence of NTSB recommendations, a lack of NTSB resources and workforce, and the challenge of supporting the growing unmanned aerial system sector of aviation.

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1. Introduction

When a major crisis or disaster occurs, public outcry often spurs a reflexive response by company and government actors to implement legislation, programs, or standards to prevent similar events from occurring in the future. While this "band-aid" regulatory approach to safety and reliability has been used nearly exclusively in major programs for hundreds of years, it often fails to adequately address the root cause of system failure, particularly in complex systems. Outdated regulations remain on the books despite mounting evidence of unsatisfactory control until a major accident prompts an untimely overhaul. In the area of commercial aviation, this traditional method of regulation was found to be unsatisfactory. A new model was sought which provided for the timely review and adaption of safety standards based upon continual development in science and understanding.

In modern times, where the complexity of our transportation, communications, and pharmaceutical systems has outstripped the capabilities of policy makers to understand them and outgrown the regulations initially developed to control them, a new paradigm of adaptive policy and continual knowledge investigation is in order. In a 1993 review of environmental regulations, Robert M. White, then president of the National Academy of Engineering, summarized this sentiment as "we need to build into the structure of the regulatory system means for reconsidering earlier decisions if and when our understanding changes sufficiently to call our earlier decision into question" (Uman, 1993). In *planned adaptation in risk regulation: An initial survey of US environmental, health, and safety regulation*, Lawrence McCray terms a policy approach of this structure as "planned adaptation" and suggests that some prominent American programs have successfully demonstrated the value of planned adaptation over the past century.

Policy makers face a wide gamut of challenges beginning the moment they sit down to develop regulation. Factors such as economic costs, welfare loss, international competitively, security, safety, and externalities, among others, heavily influence the resultant policy decision. Lobbyists, NGOs, aides, colleagues, the media, advisors, and constituents, just to name a few, offer information and opinions to the policy makers which constitute the knowledge base upon which the regulation is made. Finally, as if this process was not already perilous enough for the creation of effective regulation, in our fast-paced environment a policy is immediately outdated as soon as it is enacted (if not before) as information and situations change.

From this exceptionally brief description of the challenges policy makers face, two fundamental factors can be derived that determine the efficacy of a regulation:

1) The access of policy makers to superior information
2) The constant adaptation of the regulation to dynamic exogenous factors

At least intuitively, if a regulation was created by a rational policy maker informed with perfect information, and the regulation had the ability to adapt instantaneously to changes in the sector it regulated, then societal welfare would be expected to reach a global maximum.

However, this utopian policy making scenario is purely hypothetical and would be infeasible for all but the simplest, time-invariant problems. The underlying wrinkle of effective policy generation is that the same principles which lead to market failure (network complexity, externalities, imperfect information, etc) also fundamentally contribute to the challenges of constructing effective policy, and may ultimately also produce political failure. As markets and technologies become increasingly complex, and without changes in policy development to overcome regulatory shortcomings, either societal welfare or technological innovation, or both, are likely to be compromised.

Planned adaptation is an evolution of regulatory principles which has been proposed as a promising mechanism to more effectively counter market failure for highly complex systems. The underlying concept of planned adaptation is that decision makers develop regulations which are routinely audited and updated to reflect changes in exogenous factors as new knowledge is available. Additionally, a second key aspect of planned adaptation is the creation of an entity or process specifically dedicated to continually producing and assessing high quality knowledge.

This paper investigates the validity of claims that the adoption of induced-learning features mimicking planned adaptation in 1974 by the United States aviation industry has resulted in the steady reduction of fatal aircraft accidents beyond what would have organically occurred in the industry through traditional regulatory approaches. Broad understandings are sought revealing the impacts of planned adaptation in the aviation industry as well as the situational factors enabling its successful implementation. Additionally, the variance in effectiveness of planned adaptation application to commercial aviation (large public airlines), commuter aviation (private business jets and small commuter services), and general aviation (private aircraft) is explored. Finally, an

expansion of the NTSB planned adaption model to commercial unmanned aerial systems operation in the national airspace is cogitated.

2. Research Approach

The commercial airline industry has been proposed as an example of planned adaptation by Lawrence McCray, Kenneth Oye, and Arthur Petersen. They identified multiple indicators, such as a separate knowledge creation authority (the NTSB) and a marked safety improvement, which at first pass suggested the effective implementation of planned adaptation. However, a deeper investigation must be conducted to confirm with a relative degree of confidence that any changes documented in the safety of flight have been a result of planned adaptation rather than conventional market powers or political action.

To gain such insight, the concept of planned adaptation in aviation is evaluated through three lenses. Firstly, a policy review is conducted to establish a foundational understanding of the role of regulation in the airline industry. Of particular focus was how market failures and political failure shaped the development of regulation and the structure of the industry. The policy review identifies what aspects of planned adaptation were implemented at which point in history, and what industry shocks prompted their implementation. The periods and inflection points identified in this phase of the study enable further comparisons of regulatory approaches and safety impacts.

The study then continues by identifying key markers of planned adaptation in the current NTSB model. A review of the NTSB investigation and recommendation procedures is conducted with a focus on how these enable credible knowledge assessment. The FAA capability to either accept or ignore NTSB recommendations and what mechanisms the NTSB may influence this discussion is discussed in light of how this degrades, or potentially enhances the efficacy of planned adaptation. An attempt is also made to assess the impact of the NTSB on the safety of the aviation industry. A review of select accidents and the resulting NTSB/FAA response is conducted and a study of the technological advancements enabling higher safety standards is evaluated. An attempt is made to determine whether these safety and technology improvements could have occurred organically as the result of natural market and regulatory action or if they were only achievable due to the planned adaptation model.

Finally, a series of critical assessment exercises are conducted to identify what key factors enabled the effective use of planned adaptation in the commercial airline industry in the past four decades. Criticisms of the NTSB model are presented and the capability of the NTSB to continue to provide credible knowledge assessment to improve aviation safety is reviewed. Conclusions are also reached about the capabilities of the NTSB model to effectively guide regulatory action in the general aviation and unmanned aerial system market sectors.

3. The Evolution of Regulation in the Airline Industry

Of particular interest to this study is the time-wise evolution of aviation policy and regulation. The US government's role in aviation, which was perhaps more extensive than in any other form of transportation, was a key factor shaping the structure, institutions, and business practices of the industry today. In a sense, the history of the aviation industry may be thought of as a balancing act, perhaps even a dance, between market forces and government regulation (Quilty, 2005). To better understand how and why the National Transportation Safety Board (NTSB) was devised and implemented, a review of crucial elements of political economy in the airline industry over the past century is proffered.

Just over a decade after the Wright brother's first flight on the sands of Kitty Hawk, Tony Jannus piloted the first commercial airline flight in the United States on New Year's Day, 1914. The founder of the St. Petersburg–Tampa Airboat Line, Percy Fansler, made the following statement about the historic flight, "The Airboat Line to Tampa will be only a forerunner of greater activity along these lines in the near future… what was impossible yesterday is an accomplishment of today… while tomorrow heralds the unbelievable" (Michaels, 2014). Today, a century after this historical first flight, commercial airliners transport over 3.1 billion passengers a year and support a substantial percentage of world trade (ICAO, 2013). Percy Fansler's description of the future airline business as "unbelievable" was certainly warranted and perhaps even understated.

The evolution of the airline industry from a project of two bicycle mechanics on a beach in North Carolina to a foundational pillar of the modern economy was a tumultuous process. If the evolution of the "airline industry" is imagined as the simultaneous development and market implementation of complex technologies (airplanes, radar, air traffic control), international politics (air rights, coordination, standardization), and socio-technical experimentation (how to make a

consumer comfortable in a metal tube miles in the air completely beyond their control), then it is truly a wonder air travel has become exceptionally safe and nearly ubiquitous in a little over a century.

Despite this remarkable future, the young aviation industry was slow to start. During the first few years of flight, aircraft development and operation was primarily a military interest or a spectacle to entertain the masses supported by private prize funds. Governments tended towards a Laissez-fair stance of regulation and the budding industry experienced rapid improvements in technology through the efforts of innovators and daredevils who assumed high risk and frequently lost their lives (Brady, 2000). Besides these few early adopters, a widespread aviation market did not develop as a majority of potential consumers maintained their preference for slow and reliable ground transportation over the well known and significant risks of airplane travel (Boyd, n.d.).

The onset of World War I marked the first major government interaction with aviation. Trench warfare techniques and advanced technologies pushed European and American military leaders to recognize the value of the airplane for scouting and surveillance (Crouch, 2004). During this period the aviation industry experienced the first of many technological revolutions as a result of large government subsidies and research programs. Additionally, on March 3rd, 1915 (roughly seven months after the start of the war), the United States Congress established the National Advisory Committee for Aeronautics, or NACA. NACA was composed of 12 members representing government, military, and industry interests. The role of the committee was to coordinate the efforts of the numerous and diverse contributors to aeronautics in America and foster rapid development of aircraft technology (Suckow, 2009). Although this initial purpose was not regulatory in nature, the committee may be viewed as the first instance of government intervention in the otherwise free market.

Following the conclusion of World War I, military investments in the industry rapidly declined. As a result, the industry, still lacking a sustainable commercial base, briefly stalled (though it should be noted that technological advancement continued to progress rapidly due to the efforts of NACA, private innovators, and the post office airmail service) (Lawrence, 2004). It is difficult to assess the root cause of the inability for civil aviation to flourish during this time period. Although World War I had significantly advanced the capabilities and safety of aircraft, sustainable commercial carriers were unable to maintain a passenger service. The lack of public demand for

air transportation may have been a symptom of an information asymmetry between the industry and populace. If such were the case, the newness of the industry and highly publicized failures of the new technology masked the public from recognizing the improving reliability and benefits of aircraft operations.

While the airline industry may have overcome this market failure naturally, the United States Post Office acted quickly to bolster the industry and enable more efficient postal delivery by privatizing its airmail services. The Air Mail Act of 1925, or the Kelly Act, established "Contract Air Mail Routes" which provided the first stable and profitable income stream for commercial aviation. Closely on the heels of the Kelly Act, the Air Commerce Act of 1926 provided structure to the new commercial aviation industry. This action in 1926 marked the first inflection point of regulation in the aviation industry signaling the transition from a nearly completely unregulated market into 52 years of direct government oversight and control. This foundational set of regulations set the first vehicle safety standards, pilot certifications, and air traffic rules, among others (Quilty, 2005).

A significant result (as well as an intention) of these two policy actions was to use government regulatory capabilities to overcome a perceived market failure. The regulatory standards of the Air Commerce Act provided credibility and national safety standards to commercial aviation in the public eyes. The result was an immediate stabilization of the market (through the contract air mail route business) and the opening of two regular passenger airline services within the year (FAA, n.d.). The impact of these two policies is likely one of the most rapidly realized and successful government interventions in an ailing market.

A small aspect of the 1926 Air Commerce Act which would be amiss not to mention in this paper is Section 2, clause E which reads:

> *It shall be the duty of the Secretary of Commerce to foster air commerce in accordance with the provision of this Act, and for such purpose – (e) To investigate, record, and make public the causes of accidents in civil air navigation in the United States.*

This single clause established a mechanism for knowledge generation and distribution in the early aviation industry. Up to that point, no single entity had been responsible for investigating

failures. Oftentimes the public would only be informed of significant losses of life through newspaper articles whose authors did not have the access to or the expertise to understand and communicate accident causes. Through this regulatory accident, the Sixty-Ninth Congress of the Unites States not only bolstered a foundering civil aviation industry, but it also implemented a major component of the planned adaptation model. This clause represents the ideological founding of the National Transportation Safety Board. However, it would be yet another 68 years before the NTSB would be re-established as a separate entity outside the aeronautics regulatory agency and fully embrace the principles of the planned adaptation model.

During the formative years, the aviation industry had benefited from a low barrier to entry enabling countless individuals and companies to operate competitively in the market. However, as the airmail routes represented the primary income stream for otherwise struggling airlines, a government driven concentration of the industry developed where the firms who were awarded the contracts thrived while others were stunted in growth. As the industry rapidly grew beginning in 1927, numerous airlines sprouted throughout the country with hopes of securing an airmail route or attracting passengers (Davies, 1972). Due to market competition and the extreme concentration affect of airmail routes, by 1930 the industry was dominated by four major airline companies: American, Eastern, United, and Trans World (Morrison & Winston, 1995).

While the concentration of the industry due to the limited number of airmail routes could be justified as an inevitable occurrence in a single customer market, an alternative explanation is that the effect of concentration was heightened by political failure in the form of corruption. A cursory review of the 1930 Air Mail fiasco may provide credence to this hypothesis and indicate a political failure. In this scandal, Postmaster General Walter Folger Brown utilized his unilateral authority to enter into long-term airmail contracts to consolidate all airmail routes to only three companies. This action, during what later became known as the "Spoils Conference," effectively represented the creation of an oligopoly of the American airline industry (Lawrence, 2004). A senate investigation followed which reached the conclusion in 1934 that there had not been collusion between Brown and the airlines, however the long term effects of the scandal were impactful. Most significantly, the industry would remain consolidated with a limited number of large players, and secondly, the air mail routes became less profitable when they were reinstated as the government sought to foster greater competition (Davies, 1972).

As the dust settled from the Air Mail scandal, the focus of the industry shifted from the crippled airmail industry to the burgeoning passenger market. The government responded to this new capability in the Civil Aeronautics Act of 1938. The Act developed the Civil Aeronautics Authority or CAA (a precursor of the Federal Aviation Administration) to consolidate all regulation of air transportation. In addition to regulatory responsibilities, the CAA also designed and certified air routes and regulated airline fares to prevent collusion and unfair ticket prices among the few airlines.

In addition to the CAA, the Civil Aeronautics Act of 1938, Section 701 established the "Air Safety Board" with the mission of investigating accidents, discerning the probable cause, and then developing public reports, recommendations, and regulatory suggestions to prevent the recurrence of similar accidents. The Air Safety Board represents another major step of civil aviation towards a planned adaptation model. However, while the Air Safety Board was empowered to conduct knowledge generation and publically distribute its findings, the board was still under the regulatory body of the CAA and therefore was not an independent entity. This excludes the Air Safety Board from representing the fully objective knowledge source called for by the planned adaptation model.

The situation remained unchanged in 1940 by the Reorganization Act which divided the CAA into two agencies. The first was the Civil Aeronautics Board (CAB) which became responsible for rulemaking and contained the Air Safety Board. The second entity was the Civil Aeronautics Administration (referred to as CAA for the remainder of this paper) which assumed enforcement of safety regulations, certifications, and development of air traffic control (Quilty, 2005).

Over the next two decades, the aviation industry rapidly expanded operations under the tutelage of the CAA and CAB. World War II initiated a second wave of major government research and development in aerospace technologies worldwide. As a result, the commercial airline industry saw significant reliability and capability improvements as technologies trickled down from the military. The introduction of the gas turbine (or jet) engine to the airline industry in the mid 1950's revolutionized the industry by offering passengers the capability to travel long distances at speeds previously unimagined (Lawrence, 2004).

With these advances, the development of the industry and technology during this period far outpaced the regulatory advancements implemented by the CAB, and especially the air traffic

control infrastructure developed by the CAA. As a result, airline incidents and accidents continued to plague the industry as more and more flights congested the airspace and airports. The aviation industry thus came to a tipping point, to be considered the second major inflection point, on June 30, 1956 when a United Airlines DC-7 and Trans World Airlines Super Constellation collided over the Grand Canyon. The incident occurred outside the support area of the primitive air traffic control capabilities of the day and resulted in 128 fatalities. The incident was the most catastrophic in aviation history at that time and shocked the nation. When coupled with another high-profile accident in Washington D.C. seven years earlier that led to 55 civilian deaths, as well as over 254 other in-air collisions between 1948 and 1955, it became clear that there was a significant failure in the system (Simpson, 2014).

It is worth briefly pausing at this point to assess what factors in the aviation sector enabled these accidents to occur. It stands to reason that action would have been taken by the airlines to prevent the loss of lives and precious public trust posed by these accidents. Additionally, it was the sole purpose of the CAB and Aviation Safety Board to learn from previous accidents and prevent future occurrences through regulation. Despite these separate goals leading to the same end, both the market drivers and the political drivers failed to address the continuing aircraft collisions and loss of life.

A market failure in this situation can be identified due to misplaced incentives. The Aviation Safety Board ultimately determined that the 1956 collision likely occurred while the pilots of the two aircraft were treating their passengers to a view of the Grand Canyon and failed to see the other aircraft (Simpson, 2014). Traveling by airline was a luxury for passengers in the day and therefore commercial companies operated under an incentive to maximize the enjoyment of their passengers' flight, even at the potential cost of safety. Secondly, since the industry was highly regulated by the government, it had little incentive to utilize its resource for the creation of a national air traffic control system to prevent mid-air collisions. Such a task would require coordination and investment among all airlines in the network. As history shows, it is unlikely the airlines would tackle this collective action problem unless public demand made it profitable or necessary to do so (a condition which existed following the highly publicized Grand Canyon accident).

On the government side, a political failure also existed as a result of the distribution of authority over commercial aviation among multiple entities. The CAB, while responsible for regulation and rule making, did not have the authority to control the airspace and develop air traffic control regulation and infrastructure. This authority was divided among the CAA and its military counterparts. This division of roles led to ambiguous responsibility and conflicting technology development. The capabilities of the CAA were further reduced by its location in the Department of Commerce (FAA, 2014). In this position the CAA was unable to obtain proper funding and ultimately failed to rectify the failures in air traffic control in a timely manner.

Finally, an additional political failure existed which related directly to the concept of planned adaptation. While the Aviation Safety Board existed with the fundamental purpose of investigating accidents, determining root cause, and delivering recommendations to the CAB to prevent future accidents, the safety board did not function as an independent entity from the regulation making body of the CAB. Rodney Stitch has made claims that this period of aviation represents a dark history of corruption and collusion where the Aviation Safety Board intentionally omitted key findings and imperative information which would have saved lives in an attempt to protect industry and the regulatory authorities (Stich, 2007).

The public response to the Grand Canyon accident rapidly spurred changes in government regulation of the airline industry to overcome the political and market failures identified above. Congress passed the Federal Aviation Act of 1958 which consolidated aviation rulemaking and safety functions to the newly created Federal Aviation Agency (FAA). The FAA overcame many of the limitations of the CAA/CAB by being established as an independent agency and providing the FAA with sole control over national airspace navigation and air traffic control. The Aviation Safety Board remained outside of the FAA within the Civil Aviation Board.

In 1966, further steps were taken to strengthen the regulatory capacity of aviation. President Johnson developed the Department of Transportation (DOT) under which the FAA was placed with the slight name change to the Federal Aviation Administration. Additionally, the Aviation Safety Board was also relocated within the DOT and restructured as the National Transportation Safety Board. In addition to responsibilities for aircraft accident investigations, the NTSB also became responsible for investigations into other forms of transportation accidents such as railroad, marine, and highway (NTSB, 2014).

It was not until 1974, however, that the aviation sector adopted the final aspect of a planned adaptation model when the NTSB was re-established as an independent entity outside the DOT. In the Independent Safety Board Act of 1974, Section 302, Congress specifically identified the fundamental purpose why an independent organization is required by planned adaptation for knowledge creation:

> *Proper conduct of the responsibilities assigned to this Board requires vigorous investigation of accidents involving transportation modes regulated by other agencies of Government; demands continual review, appraisal, and assessment of the operating practices and regulations of all such agencies; and calls for the making of conclusions and recommendations that may be critical of or adverse to any such agency of its officials. No Federal agency can properly perform such functions unless it is totally separate and independent from any other department, bureau, commission, or agency of the United States.*

From this brief history of political economy in the aviation industry, it appears that each of the two inflection points thus far moved the industry away from market driven forces and further into government regulation. The Air Commerce Act of 1926 marked the end of aviation as an unregulated market and brought in foundational levels of the regulation. Then, the Federal Aviation Act of 1958 established much greater controls on the national airspace and regulatory efficacy of the government. However, the third inflection point of the airline regulatory discourse is embodied in the Airline Deregulation Act of 1978. Once again, the US Congress most adequately described the philosophical and economic underpinnings of the legislation:

> *An Act to amend the Federal Aviation Act of 1958, to encourage, develop, and attain an air transportation system which relies on competitive market forces to determine the quality, variety, and price of air services…*

The Airline Deregulation Act sparked a rapid period of market growth reminiscent of the formative years of the aviation industry. The major airlines formed through the concentration effects of government regulation engaged in intense competition which dramatically reduced fares, but created a hypercompetitive market. Multiple new airlines entered the market; however, the overall number of providers did not substantially grow as competitive forces maintained a

concentrated industry (Morrison & Winston, 1995). Notwithstanding the significance of deregulating on airline development, the economic effects of airline deregulation are beyond the scope of this discourse and may be readily found in other studies.

Although the Airline Deregulation Act removed many of the government economic controls of the industry, the act did not impact the safety and operational rules which the FAA maintains and enforces. New technologies, cost-cutting companies, and terrorist activities have dramatically challenged the landscape in which the FAA and NTSB operate since the deregulation of the industry. However, airline safety has continued to improve and new regulations have been developed to overcome emerging safety and operational challenges. The remainder of this paper will utilize the regulatory and political economy history provided in this section to analyze the effectiveness of planned adaptation as a regulation development and improvement mechanism in the aviation industry since 1974.

4. Markers of Planned Adaptation in US Aviation

The Independent Safety Board Act of 1974 established the final construct of a planned adaptation model in the aviation industry. The NTSB represents an independent knowledge generation and assessment body with the mandate to objectively gather, assess, and publish public data regarding accidents in the transportation industry and provide recommendations to improve safety. The FAA (as well as other relevant government agencies) acts as a regulatory and rule making body which receives the knowledge and recommendations made by the NTSB, evaluates the efficacy of the recommendations through a political and economic lens, and then updates existing regulations or develops new regulations to adapt the industry practice to new challenges of the day and age.

This structure, at least as penned in the United States Code, represents the core principles of planned adaption in action. The following sections will review how the NTSB and aviation industry display the core principles of planned adaptation as well as other markers of planned adaptation suggested by McCray in his work *Doing Believable Knowledge Assessment for Policymaking*.

4.1 Autonomy of Operations, Funding, and Oversight

Taking a deeper look into the operation of the NTSB, the markers of planned adaptation can be further reviewed. The first key aspect of the Safety Board it its independence from the Department of Transportation and all regulatory bodies it advises. This quality enables the NTSSB to provide appropriate information and oversight even if the cause of an accident may be linked to deficiencies in the regulatory system itself. Independence from the CAB or FAA was a key aspect missing from the Aviation Safety Board and original iteration of the NTSB. During these time periods, severe allegations of fraud and cover-up have been levied against the NTSB (and its predecessor) regarding the withholding of critical safety information in accident reports to allegedly shield the parent regulatory agency from political and public scrutiny (Stich, 2007). Therefore, the US Congress emphasized in the Independent Safety Board Act of 1974 the importance of NTSB autonomy for credible knowledge assessment to occur.

Due to the function of the NTSB solely as a knowledge generation and assessment source, the institution is insulated from the dangers of political failure suggested above through a number of mechanisms. First of all, the NTSB receives its budget directly from the federal budget and is not reliant upon any other agency. This prevents the board from being inadvertently subject to partisan politics which are frequently leveraged on the more polarizing entity that is the Department of Transportation. In *We Are All Safer*, Safety Board member Deborah Hersman summarizes this sentiment as "the NTSB enjoys broad bipartisan support because of our independence…"

The separation of funding also prevents retaliation from the DoT to investigation findings and recommendations which may criticize regulatory action or inaction. As discussed by McCray in *Doing Believable Knowledge Assessment for Policymaking*, some regulatory agencies may avoid the use of "extramural knowledge assessments" because there is a risk of inciting a highly publicized policy debate with significant fallout on the regulatory agency. Because the NTSB has secure funding and is mandated to investigate all accidents, this potential political failure is avoided.

Secondly, autonomy enables the NTSB to consistently investigate and create new knowledge despite changing political and industry goals. While national goals, in terms of transportation priorities and programs, are often tightly corresponded to the political cycle, the NTSB is not

typically subject to these swings. Finally, as an independent review organization, the NTSB is able to publish and publically disseminate findings and recommendations without review or approval beyond its own internal experts and board members. This fact prohibits stakeholders tampering with findings and also partially lifts the influence of institutional inertia or precedence of the regulatory agencies. Ultimately, the NTSB's congressional mandate to investigate and produce recommendations from transportation accidents ensures that high quality, credible knowledge assessment is conducted despite a variety of potentially confounding political factors.

As a government entity, the NTSB also leverages similar mechanisms as discussed above to fulfill its mission independent of potential market failures. The relatively constant government funding of the NTSB enables the organization to conduct accident and safety reviews without consideration of how to attract future funding. If the NTSB were a private knowledge creation entity, such as the numerous consulting agencies frequently employed by government agencies, then the NTSB investigation process and reporting would likely be reviewed by the DoT or industry sponsor before release. Additionally, reports may also be internally adjusted to present findings and recommendations that would lead to future contracts.

Finally, independence from the regulatory bodies provides a further benefit in that the NTSB may in some cases bypass regulatory processes to implement voluntary safety and operational changes directly in industry. A direct approach to industry may be more efficient than government regulation because industry "pull" can achieve safety critical changes much more quickly than regulatory agency "push". Additionally, some NTSB recommendations, such as bird strike reporting, are safety practices which do not necessarily need to be spelled out in law, but rather should be accepted as a responsibility of the industry. The methods through which the NTSB is able to directly affect voluntary action by industry are discussed in section 4.3.

4.2 Relevant and Credible Knowledge Assessment

A second major indicator of successful implementation of the planned adaptation model through the NTSB is the structure of the Safety Board itself and how it conducts knowledge assessment. In order to effectively produce data relevant to current industry operation and regulatory standards, a knowledge assessment organization such as the NTSB must have formal or informal connections to the salient stakeholders. The strength of these connections may be

thought of as a continuum where too little or too much stakeholder interaction and influence leads to various failures of the planned adaptation model.

Figure 1 displays such a model of stakeholder involvement in the knowledge assessment process. On the left hand of the continuum, the knowledge assessor fails to appropriately involve or communicate with the relevant stakeholders. In this case, the review strays from the core political questions and factors needed for effective regulation and instead concentrates on matters of primarily academic interest or aspects which provide the potential for future funding extensions. On the other hand, if a knowledge assessor over-engages stakeholders, then the criteria of independent knowledge assessment is lost and either Stiglerian regulatory capture by industry stakeholders or tampering by the regulatory agency could occur. Each of these conditions result in the ultimate loss of credibility for the knowledge assessment agency and a reduction in the benefits to society.

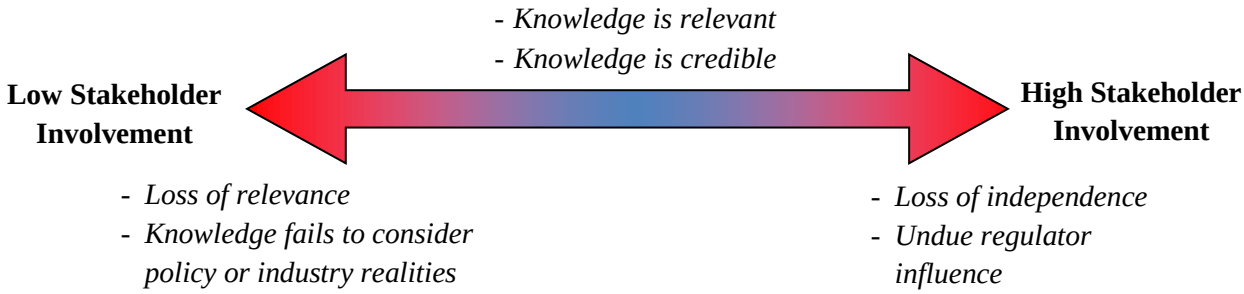

Figure 1. Continuum of stakeholder involvement in knowledge assessment. Low stakeholder involvement leads to a loss of relevance of findings while high stakeholder involvement reduces knowledge assessor independence potentially compromising credibility. Planned Adaptation calls for an appropriate balance of stakeholder participation and independent evaluation.

The assumptions made above in the continuum model of stakeholder involvement are supported by findings from workshops with federal sponsors of knowledge assessments conducted by McCray (McCray, unpublished).

The NTSB has multiple unique processes and organizational structures which enable it to effectively balance the relevance of its findings and recommendations to stakeholder needs while also preserving its credibility achieved through relative autonomy. The Safety Board is able to accomplish this precarious balancing act through:

1. An intentional selection of Safety Board members with specific skill sets and affiliations

2. The formal inclusion of regulator (FAA) and industry experts through the "party" process

The NTSB organizational hierarchy is provided in Figure 2 as presented on their official website. The executive board is composed of five members who are nominated by the president and approved by the Senate for 5-year terms. In order to provide appropriate expertise in the science of accident investigation, the Independent Safety Board Act of 1974 mandates in Section 303, clause (a) that "no less than two members of the Board shall be individuals who have been appointed in the field of accident reconstruction, safety engineering, or transportation safety." This clause has been updated to require three members of the board have technical experience and ensures that the NTSB will remain in touch with the technical side of knowledge generation and interpretation, thus protecting the credibility of the NTSB findings (Fielding, Lo, & Yang, 2011).

The same clause also asserts that "no more than three members of the Board shall be of the same political party." By limiting the political composition of the board to a simple majority, the architects of the NTSB assured that political differences would not potentially stall the knowledge generation duties of the board and that a minority party voice would always exist on the board. It is observed by the writer that the non-safety expert members of the NTSB typically have extensive service in other areas of government such as the DoT and FAA. This suggests that these appointees ground the NTSB in policy thinking and prevent the organization from straying too far from relevant knowledge generation and interpretation.

Therefore, the intentional inclusion of both safety experts and political representatives theoretically keeps the investigation activities and reports of the NTSB centered on appropriate research and recommendations which are credible and relevant.

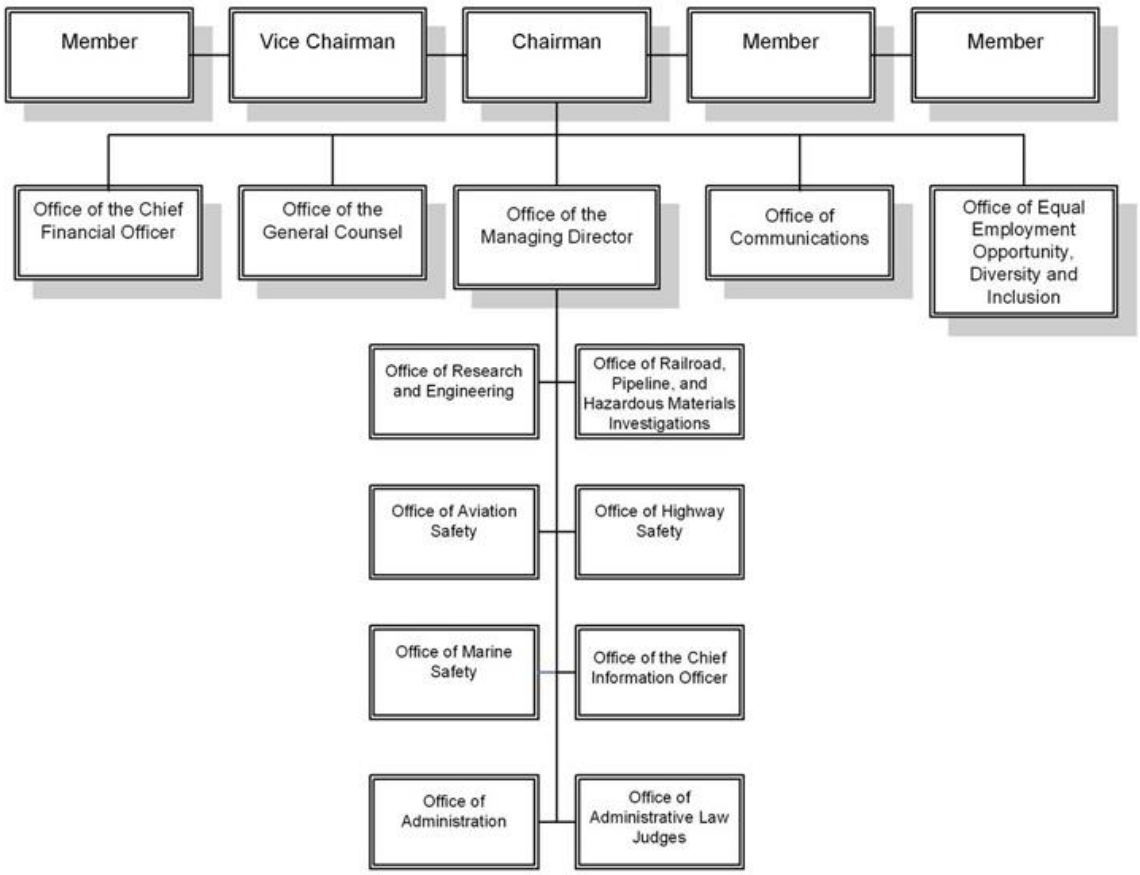

Figure 2. Executive structure of the NTSB. *Source: NTSB website http://ntsb.gov*

4.3 Influence of Knowledge Assessment

As a distinctly non-regulatory body, the NTSB aims to enhance transportation safety through the development of recommendations based on findings from accident investigations. While the absence of direct regulatory power may at first glance appear as a severe limitation on the ability for the NTSB to act decisively and affect safety critical change, the history of the organization and the structure of its investigation process suggest countervailing influence mechanisms exist. The impact of the NTSB in aviation safety has been so great indeed that is has become a matter of pointed inquiry: "this paradox of less regulatory authority yielding greater influence is one of the most striking characteristics of the NTSB" (Fielding, Lo, & Yang, 2011).

To begin to understand this "paradox", the NTSB website explicates, "because the NTSB has no formal authority to regulate the transportation industry, our effectiveness depends on our reputation for conducting thorough, accurate, and independent investigations and for producing timely, well-considered recommendations to enhance transportation safety" (NTSB, 2014). This

statement suggests that the leverage over regulation which the NTSB commands is simply the result of producing highly credible information and publically distributing this knowledge. While this may at first take appear idealistic, a review of the knowledge release process and the exogenous factors surrounding the NTSB recommendations offers some clarity as to why this organization has substantial influence and can affect safety change in regulation and industry. In all, five unique mechanisms have been identified which enable the NTSB to affect change despite a lack of regulatory power and dependent entirely upon the generation of credible knowledge.

1. Press Briefings

Following an accident involving public air transport, rail, highway, marine, or pipeline (and, as recently seen, commercial space operations), NTSB investigators travel to the incident and oversee an investigation to determine probable cause. Due to the high level of safety in the airline industry and relative infrequency of accidents, as well as the catastrophic nature and loss of such accidents, the NTSB often receives a significant level of public media attention while investigating airline incidents. As outlined in the NTSB *Aviation Investigation Manual*, a public media release must be made each day of the investigation which shares factual information and findings from the day (NTSB, 2002). These initial public announcements, while omitting speculation over causation, may serve to focus attention on any potential safety concerns of the accident.

2. Party System

During the investigative process, the NTSB is also able to exert indirect influence over stakeholders in industry affected by the accident through the "party system". This system refers to the NTSB investigation model of developing working groups composed of representatives from organizations and companies who have been selected to assist in the investigation. From a practical standpoint, the party system enables the NTSB to leverage the expertise, resources, and workforce of the parties to supplement their in house capabilities. From an influence standpoint however, the party system allows representatives from industry and experts from companies with products, personnel, or functions involved in the accident to be intimately involved in the investigative process.

While the party members are prohibited from sharing investigation information without approval of the NTSB, it is encouraged for party representatives to request the early release of

information in order to enable remedial actions by companies to potentially prevent related accidents. The party process, besides reducing NTSB costs and likely producing higher quality results than could be produced independently, allows for more efficient knowledge transfer to industry and likely enables industry to take safety critical actions long before the NTSB publishes formal recommendations (Tochen & Tobin, 2013).

3. Safety Recommendations

A third method by which the NTSB exerts influence is through safety recommendations. Perhaps the most well-known product of NTSB investigations, the safety recommendations are based upon the findings of the investigation and are published by the Safety Board with the intention of preventing similar accidents from occurring in the future. These recommendations address specific issues and specify a means by which to take corrective action. The NTSB typically generates 200 or more safety recommendations each year addressing a wide variety of transportation modes (Tochen & Tobin, 2013).

To maximize the impact of its recommendations, the NTSB distributes the recommendations through a variety of channels. First of all, the NTSB sends the safety recommendations directly to the organization(s) which it believes are most able to address the concerns and implement the corrective action. When recommendations are directed at the Department of Transportation, by law the Secretary of Transportation must formally respond to the Safety Board within 90 days and explain what actions the DoT will take in response to the recommendation. Additionally, to further formalize the process and ensure that the NTSB recommendations are appropriately considered, the Secretary of Transportation must also specifically address each proposed NTSB safety recommendation in a report to Congress each year (Lebow et all, 2000).

A second mechanism the NTSB uses to maximize the impact of its recommendations is compulsory public distribution. All NTSB recommendations are made publically available through their website and in the public docket which enables the general public, involved parties, and legal system to identify what improvements were suggested by the Safety Board. Especially in cases involving commercial airline accidents or other highly publicized incidents, the public distribution of the safety recommendations may apply pressure for the recommendation to be adopted by empowering the public or legal system to pursue accountability of the involved parties.

4. Public Investigative Hearings

A fourth method the NTSB has at its disposal to enhance the impact of the knowledge it generates during safety investigations are public investigative hearings. According to the *NTSB Aviation Investigation Manual*, the purpose of a public investigative hearing is to:

> *…allow the Safety Board to gather more facts about an accident and to put on record a substantial amount of information about circumstances relating to the accident. Hearings also allow the public to learn more about the Board's investigation of an accident for which there is substantial interest.*

Therefore, public hearings represent the ultimate method through which the NTSB may share knowledge with the general public. The public hearings represent a high level of transparency of the NTSB activities and are typically only held for controversial investigations or accidents of intense national interest. The investigative hearings are conducted in formal legal style and witnesses may be subpoenaed to provide testimony. However, these hearings are not intended to determine fault, but rather to assist in fact finding, as officially stated in the Independent Safety Board Act of 1974:

> *Transportation accident hearings are convened to assist the Board in determining cause or probable cause of an accident, in reporting the facts, conditions, and circumstances of the accident, and in ascertaining measures which will tend to prevent accidents and promote transportation safety. Such hearings are factfinding proceedings with no formal issues and no adverse parties and are not subject to the provisions of the Administrative Procedure Act.*

5. Final Accident Report

The fifth method (and final method) the NTSB utilizes to ensure the impactful distribution and consideration of the knowledge it generates is the publication of the final accident report. The final accident report contains the Safety Board's conclusions, probable cause, safety recommendations, and all factual information gathered during the investigation as well as official petitions for reconsideration and proposed findings presented by the individual parties to the investigation. The Safety Board's conclusions and recommendations are developed without review or oversight by the DoT, parties, or any other entity thereby preserving finding credibility.

A unique aspect of the final accident report is the inclusion of both the NTSB findings and recommendations as well as the findings and recommendations of the parties to the investigation. In terms of knowledge generation, the final report recognizes and mitigates the potential for bias to exist in the investigation by allowing multiple (potentially conflicting) viewpoints to be expressed. Unlike other similar knowledge generation bodies such as the National Research Council, the NTSB final report allows for differing opinions and interpretations of the data which, much like Supreme Court rulings, enables the stakeholders and regulatory agencies to consider multiple viewpoints. The breadth of these reports may enhance a regulatory agencies capability to identify needed changes in the recommendations themselves based upon changes in exogenous factors that may occur following the issuance of the NTSB final accident reports. In a sense, the NTSB is including in the final report an understanding that more knowledge may become available or situations may change that could alter their recommendations.

As apparent through the above five mechanisms, the NTSB has developed a complex strategy to maximize the impact of the knowledge it generates and recommendations it proposes. The Safety Board not only targets the change agents represented by the regulatory agencies and private industry stakeholders, but it also targets other entities such as the public, Congress, and legal system who can exert influence and hold the primary parties accountable for recommendation implementation. The NTSB appears to be highly self-aware of this critical aspect of its mission (ensuring the transition of investigative findings from paper to action) as evidenced by the following sentiment from the *NTSB Aviation Investigation Manual*:

> *The primary audience of published Safety Board documents is persons, groups, or organizations who can bring about changes in transportation safety through action on our safety recommendations. The Congress, industry, media, and public, who can influence the actions of the recommendation recipients, are also important audiences. The type of audience and the technical knowledge of the audience vary greatly depending on the document's subject and the safety issues presented. The Safety Board does not intend its reports and recommendations to be read only by technicians and specialists in the transportation industry….Because Safety Board documents are of interest to a varied audience, the writers, reviewers, and editors are to produce documents that can be read and understood by an educated lay person.*

5. Evaluation of Planned Adaptation Impact in US Aviation

Multiple indicators of planned adaptation in US aviation were presented in Section 4. These included aspects such as:

1) Credible and relevant knowledge generation
2) An independent knowledge generation and assessment entity
3) Mechanisms to provide decision makers and influence actions with credible knowledge,
4) The review of existing policies and practices once new information is available

While the review of the NTSB and the structure of the industry suggested that the enablers of planned adaptation exist, an overview of the safety history of the airline industry is necessary to identify the actual impacts of the model. The Independent Safety Board Act of 1974 constituted the final development of planned adaption in the US aviation industry. Therefore a review of airliner accident data over the past century was conducted with a focus on if inflection points exist when the NTSB was developed in 1967 and when it became independent in 1974.

Figure 3 displays the total number of fatalities and fatal accidents by year for the worldwide airline industry. Specific data was not readily available for American operations only; however, based upon the trends presented in Figure 4, it is assumed that world airline accident and fatality rates resemble American trends and may be used as a proxy for aviation safety in the United States. Figure 3 suggests that the total number of airline fatalities corresponds to the trend of the total number of airline accidents as the two data sets display similar trends. Therefore, each of these metrics may be used to assess the overall safety of the airline industry and any impacts which planned adaption may have had.

Figure 3 suggests that airline casualties significantly rose during the rapid expansion of the commercial airline industry following World War II; at this time the airline industry was primarily centered in the United States and Europe. The industry experienced a period of declining casualties until 1956 at which point the total number of casualties again began to rise. From the casualty data in Figure 3 alone, it can be seen that the total number of airline casualties continued to increase after the introduction of the NTSB in 1967 and appeared to decrease following the Independent Safety Board Act of 1974. However, without viewing the fatality data with respect to the total

number of flights and passengers in the network, these trends offer little insight into the impact of planned adaptation in aviation.

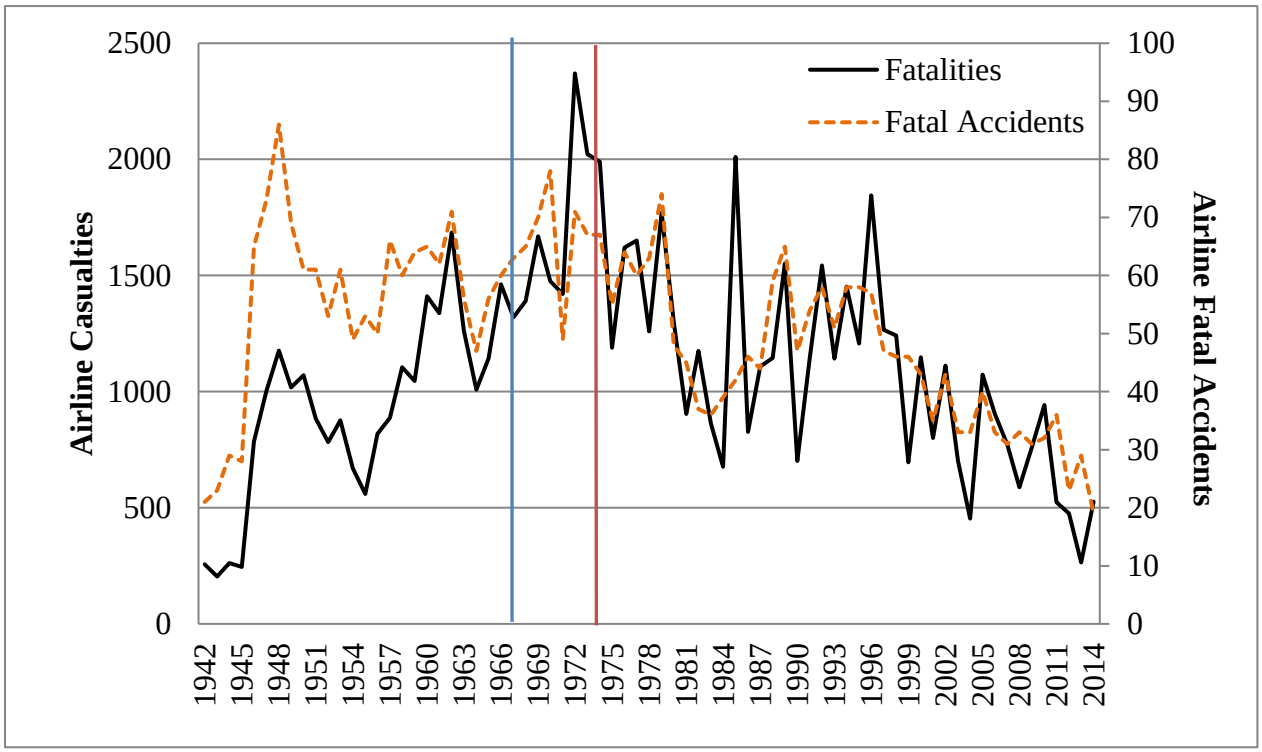

Figure 3. Worldwide airline casualties and fatal accidents since 1942 with NTSB creation in 1967 notated by a blue vertical line and the re-establishment of the NTSB as an independent board in 1974 notated by a red vertical line. Fatality data retrieved from the Aviation Safety Network.

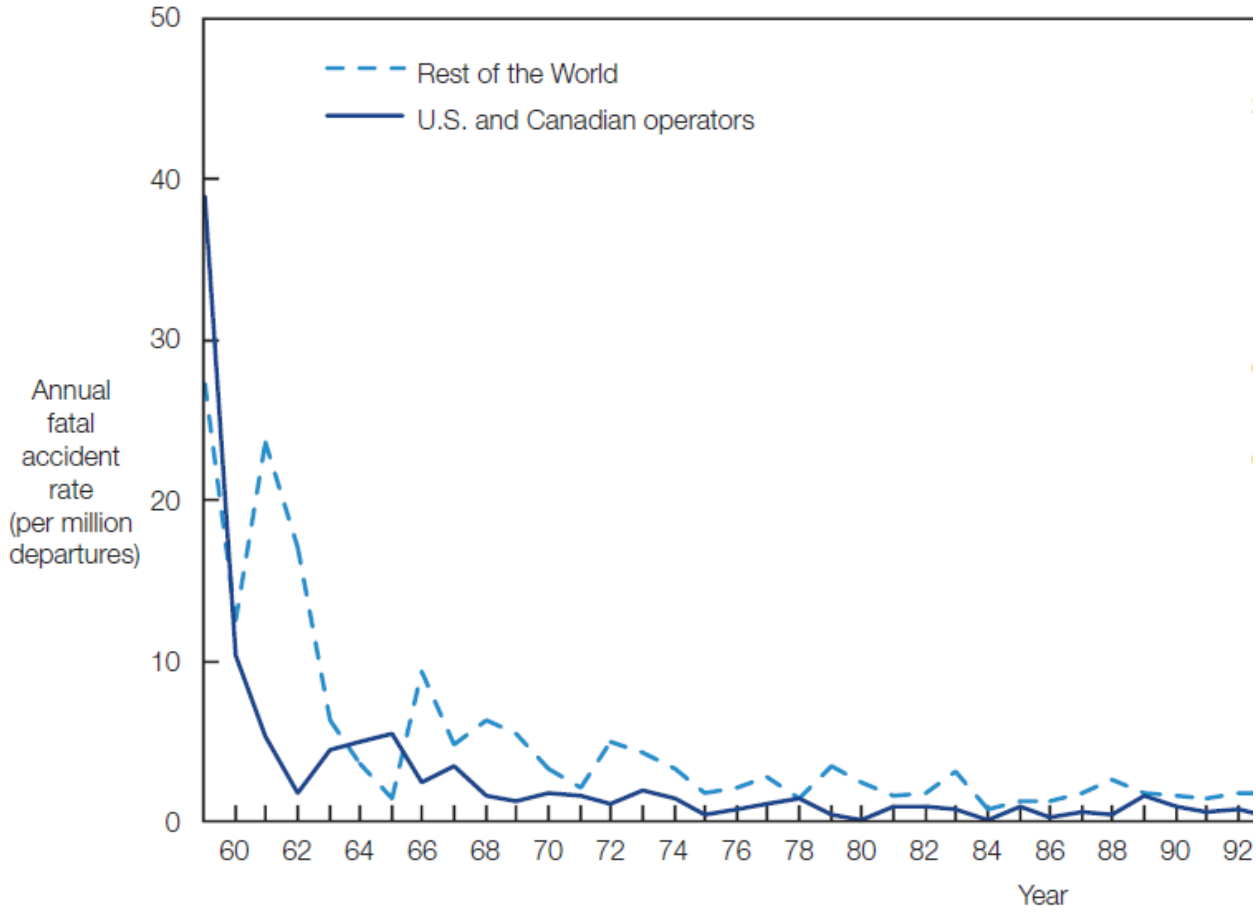

Figure 4. Annual airline fatal accident rate for US/Canadian operators and operators in the rest of the world. The trends suggest that the world fatal accident rate is similar to the US fatal accident rate and may be used as a proxy metric. Figure 4 is reproduced from the *Statistical Summary of Commercial jet Airplane Accidents* conducted by Boeing.

Figure 5 presents the fatal accident rate normalized by the number of airline operations per year (presented as fatal accidents per million departures). The total number of departures of the world industry is also presented to display the steady growth of the industry in contrast to the diminishing relative accident rate.

Figure 5 suggests that the relative frequency of fatal accidents in the airline industry has been declining since 1950 despite the increase in overall airline casualties and accidents seen in Figure 3. This apparent difference is a result of the rapid rise in the number of departures which led to the simultaneous occurrence of more accidents by number in the industry despite an improvement in relative safety per flight. Miner, Nisbet, & Elder also fitted a regression curve to the fatal accident rate data in Figure 5 which suggests that the rate of improvement in airline safety has

actually been decreasing since 1950, though still improving. This trend is reasonable as it should be expected in any industry that initial efforts at improving safety will tackle "low hanging fruit", or projects which have relatively significant safety improvement effects for relatively low investment or effort. As time progresses and the industry matures, it would be expected that achieving incremental increases in safety would become more difficult as the needed safety improvements become more expensive and result in less dramatic increases in safety.

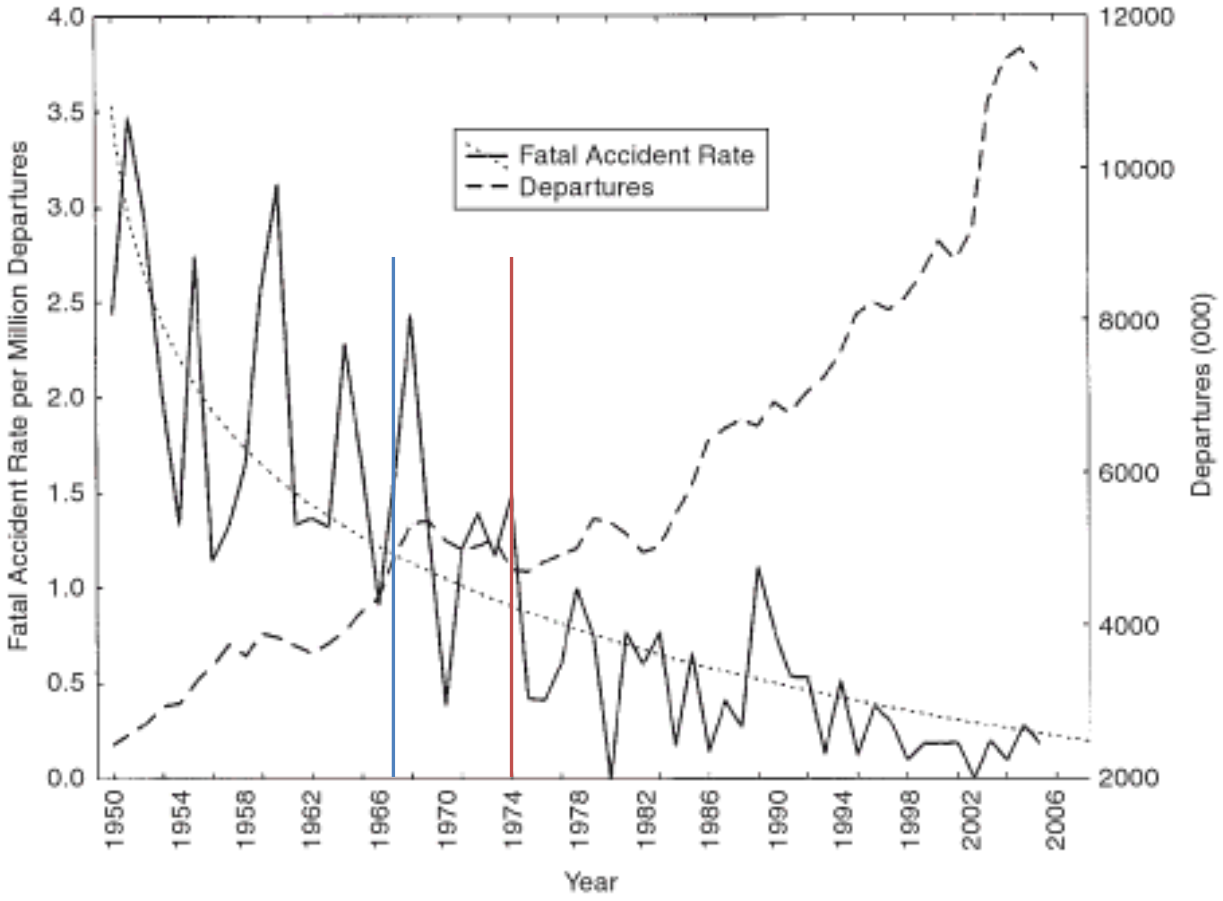

Figure 5. Worldwide airline fatality rate per million departures since 1950. The NTSB creation in 1967 is notated by a blue vertical line and the re-establishment of the NTSB as an independent board in 1974 is notated by a red vertical line. Figure 5 is reproduced from the *Handbook of Statistical Analysis and Data Mining* by Miner, Nisbet, & Elder.

Although Figure 5 suggests that the aviation safety has been constantly improving since 1950 and was improving at a faster rate before the planned adaptation model was implemented, it is not reasonable to say that planned adaptation did not impact aviation safety. By the same token, the immediate reduction of the fatal accident rate following the Independent Safety Board Act of 1974

also does not assert that planned adaptation was solely responsible for the improvement in airline safety since 1974. Rather, Figure 5 may be used as a reference to understand the potential impacts of planned adaptation on aviation and the overall safety trends of the industry, but a discussion of the NTSB knowledge generation and FAA regulatory efforts and track record since 1974 will more adequately provide insight into the research inquiry.

Since 1967, the NTSB has investigated more than 132,000 aviation accidents from which it has issued 13,000 safety recommendations to more than 2,500 distinct recipients (NTSB, 2014). Of those 13,000 recommendations, more than 80% have been accepted and implemented in industry or regulation (Tochen & Tobin, 2013).

Has the reduction in fatal accident rate been a natural development based upon the growth of the aviation industry? Would the same improvements in safety have been achieved without the development of the NTSB and the 13,000 safety recommendations they produced? While it is not possible to determine how the industry would have developed without the investigation and knowledge generation assistance of the NTSB, a review of the types of safety recommendations generated and implemented my provide insight into the questions above.

Gas turbine disk failures have been a problem which plagued jet aircraft since their introduction into service. These components rotate at extreme speeds under high temperatures which lead to degradation of the component over time. Multiple highly publicized, fatal accidents caused by turbine disk failures through the years lead to quick regulatory and industry action to redesign aircraft or change procedures. It could potentially be assumed that market forces, such as the loss of vehicles, personnel, and life in these accidents, may have organically led to the same safety improvements as those recommended by the NTSB and subsequently regulated by the FAA.

However, following a series of non-fatal turbine disk failures, the NTSB ultimately recommended and the FAA levied additional new inspection regulations, tools, and techniques on the industry (NTSB, 2005). Because the accidents leading to these more recent recommendations were non-fatal and resultantly attracted relatively low levels of public attention, it is unlikely that the competitive market would have organically adopted these additionally safety improving practices. Without the NTSB and planned adaptation, a collective action problem would have existed where an airline would not have wanted to adopt these standards and incur the additional

costs unless all other airlines would simultaneously adopt them; this would have likely led to none of the airlines enhancing their safety. Furthermore, the FAA on its own would have been unlikely to review and update the standards without the NTSB because these incidents were non-fatal and did not attract congressional or public attention to drive FAA action. Therefore, these turbine disk failures may represent a scenario where safety improvements were only possible through the planned adaptation model.

Another candidate situation involves NTSB investigations of non-fatal accidents in the Unites States and abroad caused by poor landing gear design (NTSB, 2005). Even more than the previous example, typical regulatory policy and market forces without the planned adaptation model would have been unlikely to enhance aircraft landing gear design, inspection techniques, and maintenance procedures without the planned adaptation model. The FAA and industry would not likely have taken such actions to improve safety based upon these relatively low-cost failures, many of which occurred outside the United States.

A final example situation revolves around NTSB and FAA efforts to change "cockpit resource management," or the operational procedures of an aircraft. Several airline accidents in the 1960's and 1970's were determined to be caused by dangers introduced to aircraft operation through the "culture and work environment" of the cockpit crew (NTSB, 2005). In this case, the airlines would likely have had difficulty improving safety on their own as the airline employee unions were quite powerful and may have prevented management tampering in operational procedures. At the same time, the FAA may have also found it difficult to create regulation controlling crew procedures and interactions without the credible knowledge generated by the NTSB which pointed to these aspects as the primary cause of accidents.

Through the review of dozens of significant NTSB recommendations and activities similar to the previous three examples, a few trends have been identified which represent situations where the planned adaptation model forced safety improvement which were not likely to have occurred through normal market and regulatory activities. These situations include safety improvements resulting from:

- Non-fatal accidents
- Accidents occurring outside the United States

- Accidents involving extreme weather situations
- Accidents which could be attributed to operator error
- Safety improvements requiring significant vehicle overhaul to protect against relatively severe, but infrequent occurrences
- Accidents which were resultant of "network" effects outside the control of a single airline (such as Air Traffic Control)
- Safety improvements which require all airlines to act simultaneously to prevent any one airline from realizing a competitive advantage
- Accidents requiring extensive investment of time and resources to determine probable cause
- Safety improvements of reporting systems which do not immediately improve safety or address the root cause of an accident

The conditions above can be deconstructed and expressed quite succinctly. The model of planned adaptation in US aviation appears to have driven safety to a level which would not have been achieved organically by standard market forces and regulatory action in situations where the cost of change is high, public awareness of the problem is low, accountability for failure can be deflected, or when change requires government coordination and implementation.

Based upon the conditions identified above and the continued safety improvements in the commercial airline industry since the inception of the NTSB, it appears to be very likely that the planned adaptation model adopted in the US aviation industry has increased the safety of the industry. However, it should be noted that the NTSB has not been as successful at reducing GA accident rates which remain roughly 40 times greater than for airline operations. Similarly, the NTSB has also been less effective at reducing accident rates for the business and small commuter vehicle industry which exhibit accident rates roughly six times higher than the airline industry (NTSB, 2014). The following section discusses factors that have enabled the model of planned adaption to be successful in the aviation industry. It also identifies potential limitations of the model which result in the effectiveness asymmetry seen between commercial airline and GA safety rates.

6. Abstracted Enabling Factors and Limitations for Planned Adaptation

As noted by McCray and Oye in *Adaptation and Anticipation: Learning from Policy Experience*, "there are few attested example of planned adaptation in federal practice." Section 2 presented the history and relevant policies over the past century which led to the model of planned adaptation being developed in the US aviation industry. However, what were the specific factors which enabled the model of planned adaptation to *succeed* and *survive* in the Department of Transportation while other comparable federal agencies have not adopted such a model? Secondly, can any conclusions be drawn about limitations of planned adaptation based on what factors and mechanisms have enabled the NTSB to significantly improve safety standards in commercial aviation, but not reach similar levels of success in other forms of transportation including general aviation and highway travel?

6.1 Influence through Leveraging Public Interest

Perhaps an initial explanation of the success of planned adaptation in air transportation can be understood through a review of the five mechanisms of influence presented in Section 4.3. The ultimate effect of these five mechanisms is to enhance the likelihood that the recommendations and knowledge assessment conducted by the NTSB ultimately leads to regulatory review or direct safety action by industry. A clear trend can be seen among the mechanisms that each one serves to enable knowledge distribution in a new "venue". In *Doing Believable Knowledge Assessment for Policymaking*, McCray suggests that "change-of-venue" occurrences, where external knowledge assessment by entities such as the National Research Council heighten the public awareness of policy debates and increase fallout on the regulatory agency, may be a factor resulting in the "recent stagnation of the class of knowledge-assessing organizations". However, for the NTSB, change-of-venue tactics appear to be one of the primary strategies the Safety Board has to exert influence and affect regulatory or industry change.

The NTSB overcomes the challenge McCray presents primarily because it is fully independent from the regulatory agencies it serves and is mandated to conduct knowledge assessment regardless of the regulatory agencies' desires. Therefore, the NTSB is able to leverage knowledge distribution in increasingly widespread venues, from distribution in the party system among select industry experts up to publically televised national investigative hearings, to apply pressure on

regulatory agencies and industry stakeholders to act upon their recommendations. The ultimate measure of the effectiveness of this approach is that the NTSB, with no official enforcement capabilities, has been able to realize an 80% acceptance rate of the nearly 14,000 safety recommendations it has issued since 1967. Even more impressively, 90% of the recommendations since 1967 have been "resolved in a manner deemed 'acceptable' to the NTSB" (Tochen & Tobin, 2013).

These findings suggest that planned adaptation in the aviation industry may benefit from the ability to exert significant public pressure on the regulatory agencies and industry to adopt the recommendations it produces *for high visibility accidents*. The qualifier attached to the end of the previous statement offers an insight into why the NTSB has not been as effective at improving safety for GA and highway traffic. In the case of commercial airline accidents, the typically high casualty rate of the accident as well as the infrequency of incidents in a widely assumed "safe" system causes immediate high public visibility; the Institute for Civil Justices goes so far to say that "major accidents have come to be viewed as nothing short of national catastrophes" (Lebow et all, 2000). As shown above, the public interest enhances the NTSB capabilities to affect safety standard change based on knowledge assessment of the accident. However, GA and highway motor vehicle accidents typically involved fewer casualties and occur in a system where the users have greater perceived control over risk. Therefore these incidents, which occur two to three orders of magnitude more frequently than airline accidents, often receive relatively small public attention and therefore compromise significant capabilities of the NTSB to affect change.

Enabling Factor 1: The ability of planned adaptation to affect regulatory change is directly linked to the public interest in the matter, where larger involvement by the public facilities more likely regulatory action.

6.2 Mandated Periodic Knowledge Assessment

A second potential enabler behind the success of the planned adaptation in the airline industry is the mandate of the NTSB to investigate all commercial transportation accidents, determine root cause, and issue recommendations for improvement where necessary. This model is fundamentally different than the more common approach of funding the National Academy of Sciences or a private consultant firm to produce independent knowledge assessment at arbitrary intervals. The

latter method for knowledge assessment has been criticized by federal agencies for taking too long or being too uncontrollable while simultaneously being criticized by stakeholders as a mechanism for policy makers to postpone key decisions or deflect responsibility by claiming a lack of credible information (McCray, unpublished).

Since the NTSB receives consistent funding by an entity with no stake in the studies being conducted, it is able to avoid both the lack of use by federal agencies trying to avoid public awareness of the issues as well as over-use by federal agencies as a stalling technique. The unique charge of the NTSB to investigate every commercial transportation accident since 1967 has enabled the Safety Board to provide frequent recommendations for safety improvements in response to both minor and significant changes knowledge and the industry. This model of constant, predictable knowledge assessment is similar to the standout federal planned adaptation programs of EPA ambient air standards and US FDA pharmaceutical regulation identified by McCray, Oye, and Peterson.

While this condition of the NTSB explains how it has remained in existence for nearly 50 years, it offers little additional insight into why the organization has been more effective at improving safety for commercial airliners than in GA operations. Based upon this factor alone, it is actually quite confounding that GA did not improve more rapidly than commercial aviation since the NTSB investigated nearly 1500 GA accidents in 2012 versus only 27 air carrier accidents (NTSB, 2014).

Enabling Factor 2: The effectiveness of planned adaptation to impact regulation over time is dependent upon mandated periodic knowledge assessment either conducted at regular intervals, or in response to a specific, recurring event.

6.3 Advocating for Adaptation Based on Knowledge Assessment

Another relatively unique aspect of the US aviation planned adaptation model is the advocating for adaptation and change which the NTSB conducts through the "NTSB Most Wanted List." The NTSB produces this list each year and highlights the top ten safety issues and recommendations which they believe industry or regulatory agencies should take action on. The list itself could perhaps be thought of as the sixth mechanism (of the five presented in section 4.3) that allows the NTSB to raise public awareness on the issues and pressure recommendation adoption and action.

The 2011 NTSB Chairman, Deborah A.P. Hersman, described the most wanted list as "the most powerful tool we have to highlight our priorities" in a 2011 press release. She went on to explain that "the NTSB's ability to influence transportation safety depends on our ability to communicate and advocate for changes" (NTSB, 2011).

The explicit action taken by the NTSB to advocate for safety adds a new twist to the concept of planned adaption as presented in current literature. One of the primary precepts of planned adaptation is that the knowledge generation function is conducted by an entity which has no vested interest in the field and is able to be effectively unbiased. However, the NTSB most wanted list expands the Safety Board's role beyond fundamental knowledge generation and assessment to a new role including advocating for recommendation implementation.

Does the NTSB violate the principles of planned adaptation by taking an active role in the adoption of its recommendations? If the most wanted list is viewed simply as another mechanism to disseminate credible knowledge to the general public and relevant stakeholders, then the NTSB does not violate the core principle of unbiased knowledge generation. Similar to the Safety Board's activities to share information through press briefings and public investigative hearings, the most wanted list may be considered another avenue for the distribution of refined factual information regarding the safety of the aviation industry.

The advantage of such advocacy is that it provides a means by which to ensure the persistence of recommendations and relevance of credible knowledge when the stakeholders or regulatory agency may be adverse to action. Many of the NTSB most wanted goals have remained on the list for multiple years following initial recommendation in an accident report. These recommendations, deemed very significant by the knowledge assessment agency yet excluded from implementation by the regulatory agency, are able to "stay on the radar" or policy makers and have a chance of being re-considered for implementation as conditions change or public pressure increases. In more extreme circumstances, advocacy is an effective method to prevent recommendations from being produced and then concealed by the regulatory bodies to never be enacted.

The NTSB has utilized the most wanted list to advocate for safety changes in both commercial aviation as well as general aviation. Since 2011 general aviation has been a specific area of improvement called for in the most wanted list.

Enabling Factor 3: The ability of planned adaptation to affect regulatory change may be enhanced through information distribution-based advocacy by the knowledge generating entity.

6.4 Additional Enabling Factors

The three enabling factors from above have been abstracted from the structure and success of the NTSB and planned adaptation model in commercial aviation. Of the three identified, only enabling factor 1, which considers the degree of public interest of the accident, offers potential insight into why the NTSB has achieved greater safety in commercial aviation than general aviation. Through an investigation of the differences between civil and general aviation, multiple additional factors can be identified which may potentially contribute to the success of, or impose limitations on, the planned adaptation model.

One of the primary differences between general aviation and commercial aviation is the number of operators. Commercial aviation is dominated by four primary airlines which carry a large majority of all commercial traffic in the United States (Bureau of Transportation Statistics, 2014). These commercial carriers operate a highly consolidated, rather standardized business. Pilot training and capabilities, as well as the aircraft used in commercial aviation, are also quite homogenous. This may enhance the effects of planned adaptation because the regulatory agency and the NTSB has relatively few individuals and companies it needs to interact with in order to make sweeping safety changes.

The general aviation industry on the other hand is composed of tens of thousands of operators ranging from business jet pilots to emergency medical service helicopter services to privately owned and operated vehicles. These operators, while participating in general certification and training procedures, often have little coordination or connection with the GA industry as a whole. Therefore, a situation emerges where the regulatory agencies and NTSB are unable to interact with every GA operator.

The lack of consolidated control of the GA industry limits the capability of planned adaptation to effectively work with relevant stakeholders to review accidents or existing regulations and update them as necessary. The capabilities, vehicles, and operations of the GA industry are exceptionally diverse compared to the rather homogenous commercial fleet and operations which further exacerbate the challenge of producing and enforcing effective safety regulations. While the NTSB has continued to make safety recommendations for general aviation and include topics in their most wanted list, associated safety regulations have been slow in forthcoming due to exterior factors related to the decentralization of control and heterogeneity of the industry. The NTSB expresses the failure of planned adaptation to address the safety of general aviation when it states, "perhaps what is most distressing is that the causes of GA accidents are almost always a repeat of the circumstances of previous accidents" (NTSB, 2014). Despite effective knowledge assessment, planned adaptation has not been as effective in GA as in commercial aviation potentially due to the structure and composition of stakeholders in each industry.

Enabling Factor 4: The ability of planned adaptation to develop effective regulations for an industry may be enhanced if the industry is composed of a consolidated group of stakeholders involved in homogenous activities. Oppositely, the effectiveness of planned adaptation may be reduced if the industry exhibits decentralized control and heterogeneous activities.

A second factor which may contribute to the difference in impact of the NTSB and planned adaption between commercial aviation and planned adaption is the nature of the consequences of failure. In commercial aviation, an airliner accident may lead to the injury or death of a large number of individuals who may be from geographically diverse areas. Additionally, unlike those passengers who initially took to the skies early in the century, today's customers do not assume risk and have the expectation of safety.

Conversely, in general aviation accidents typically involve the injury or death of a small number of individuals who are typically from a specific geographic area. Those pilots who own and operate their own vehicles are statistically most likely to be involved in accidents; however, in most cases they understand and accept the risk they are taking.

The ultimate result of these differences is that commercial aviation accidents have a much higher propensity to become focal points of public attention. A major airliner accident may touch dozens of communities around the country inciting inquiry into the cause of the accident and a demand for action. Additionally, flights in the US carry nearly 750 million people each year (Bureau of Transportation Statistics, 2014), therefore any airliner accident causes a significant percentage of the population to temporarily acknowledge the risk they assume by flying and demand action to lower that risk. A general aviation accident may only affect a single family or town and will likely not elicit the same degree of public attention.

While these last few differences between GA and commercial aviation are not included as an enabling factor (since they simply influence enabling factor one, or public interest), they have been included in Table I. Table I lists the unique factors of the two aviation sectors discussed and enables a holistic picture of how these factors may contribute to the effectiveness or limited success of the planned adaptation model in US aviation.

Table I. Potential Impact of Sector Specific Factors on Planned Adaptation Effectiveness

Aviation Sector	Sector Specific Factors	Planned Adaptation Result
Commercial Aviation	- Consolidated control - Homogenous vehicles, pilot training, and operations - High public visibility - Unassumed risk by customers - Widespread impacts of accidents	Most successful
Commuter and Business Aviation	- Semi-distributed control - Homogenous vehicles, pilot training, and operations - Low public visibility - Unassumed risk by customers - Localized impacts of accidents	Less successful
General Aviation	- Distributed control - Heterogeneous vehicles, pilot training, and operations - Low public visibility - Risk accepted by customers - Localized impacts of accidents	Least successful

7. Continued Operation of the Planned Adaptation Model

While the prior review of the NTSB displayed the organization's clear effectiveness in reducing aviation accident rates and identified multiple factors which have facilitated the successful implementation of planned adaptation in commercial aviation, the NTSB has been subject to significant criticisms of its model and may be at risk of, or currently exhibiting signs of, a failure to continue to effectively complete its mission. The challenges levied against the continued functioning of the NTSB as an effective knowledge assessment entity are as follows:

1) The party system of the NTSB no longer functions as originally intended and introduces substantial bias to the safety recommendations and the potential for industry or FAA capture of the Safety Board
2) The NTSB has failed to adapt itself to changes in the industry and is at risk of no longer producing relevant recommendations
3) The NTSB no longer receives the resources necessary to conduct robust and credible knowledge generation and will not be capable of handling future growth of the industry as well as the introduction of unmanned and autonomous vehicles

The first of these challenges the assumption that the Safety Board is fully independent in investigative and knowledge generation activities. The party system of the NTSB has been identified as a key element of the Safety Board's structure which enables it to conduct high quality, relevant investigations with relatively few employees and resources. Furthermore, the party model is intended to even enhance the impact of safety recommendations by allowing companies to be familiar with their development and capable of acting upon key knowledge before official recommendations are prepared or regulation is written. The developers of the NTSB recognized that including parties in the investigation who have a financial, ethical, or legal stake in the findings could bias the results of the Safety Board. They sought to counter these aspects by removing the assignment of fault from the purpose of the investigation as well as prohibiting findings from being shared without permission. They also ensured the Safety Board made its recommendations and findings independently.

However, while these mechanisms may have enabled the party system to function unbiasedly for many years, a RAND Institute for Civil Justice report reveals that these controls may be eroding.

> *The NTSB must work with parties involved in a crash; there is insufficient in-house expertise within the agency itself. However, this presents a clear and present danger to the integrity of the investigative process – parties that face potentially enormous economic losses if they are found to be the cause of an accident could attempt to disrupt or bias an investigation…Many observers and stakeholders openly expressed a belief that the NTSB's technical capabilities had seriously eroded and that investigations were being hampered by an overloaded staff that was increasingly insulted from the aviation community…Many stakeholders cited, for example, growing tension between the NTSB and aviation regulators at the Federal Aviation Administration (FAA). Others expressed concern that the NTSB's limited staff was no match for the opposition of large commercial firms facing large potential losses.*

Such increased vulnerability to influence by the FAA or industry as described in the RAND report could potentially lead to the NTSB becoming captured by these entities. Rodney Stich has strongly expressed his beliefs that the NTSB was captured by the FAA for some time and has withheld key findings or supporting information from significant investigations as a result. There is also reason to propose that the NTSB has become captured by industry with respect to findings on accidents involving potential pilot error. (McCray, n.d.) suggests that other knowledge assessment entities involved in planned adaptation have found "some subjects just too hot to handle." The assignment of fault of multiple recent, and significant, airline accidents to "pilot error" may be an example of this principle. The NTSB may be avoiding addressing potential issues regarding cognitive engineering and the human-automation interface in order to prevent significant unrest in the industry and opening up a new area of potential legal action.

As the commercial airline market continues to become more competitive with fewer players and higher stakes riding on each accident, the NTSB party process will continue to become more and more hazardous for unbiased knowledge generation. Again, the RAND report exceptionally described the new challenges:

> *A very real, albeit unintended, consequence of the NTSB's safety investigation is the assignment of fault or blame for the accident by both the courts and the media. Hundreds of millions of dollars in liability payments, as well as the international competiveness of some of America's most influential corporations, rest on the NTSB's conclusions about the cause of a major accident. This was not the system that was intended by those who supported the creation of an independent investigative authority more than 30 years ago, but it is the environment in which the investigative work of the agency is performed today.*

The second challenge against the continued functioning of planned adaptation between the NTSB and FAA is that the model has failed to adapt itself in response to changing exogenous conditions and is at risk of no longer producing relevant results. Dr. Nancy Leveson provides an example of this change by suggesting that modern aircraft and their associated software have become so highly complex that the investigation models traditionally used in accidents no longer lead to appropriate identification of cause and improvement recommendations (Leveson, 2004).

The findings of the RAND report also support the concept that the NTSB has failed to adapt its processes to reflect changes of the day and age. In particular, the RAND report highlights that "the NTSB should move away from simplistic, one-line probable cause statements and instead *consistently* adopt a comprehensive statement that reflects the reality that a modern aircraft accident is rarely the result of one error or failure." In these two ways, and potentially many others, the NTSB has failed to adapt itself since 1967 and may experience a lack of relevance of the knowledge it generates.

Lastly, the RAND report raised significant concerns that the NTSB no longer possess the budget and staff to properly investigate and develop safety recommendations from the ever-growing aviation industry. From the findings of the RAND report, the NTSB staff works 50 hour work weeks on average and beyond 60 hour work weeks during major accident investigations. General aviation accidents sometime receive cursory telephone investigations due to lack of workforce and time. Furthermore, the NTSB is losing its technical capabilities and capacity to independently assess accidents, lead investigations, and make recommendations as technologies become more complex and their workforce does not grow proportionality (Lebow et all, 2000).

The whole of the aviation industry is expected to continue expanding operations. This will likely place additional stress on the NTSB. In addition to this growth, a new sector of aircraft operations in the form of Unmanned Aerial Systems (UAS) is also beginning to appear in the aviation arena. A significant question of the author is how the current model of planned adaptation will adopt to handle this next market sector. As current laws read, the NTSB will not be responsible for investigating accidents of UAS (as they do not typically involve people) and therefore will not generate knowledge to guide regulation. This situation means that planned adaption is not functioning for UAS and the FAA will be on its own to both assess knowledge and develop regulation.

At this time, the FAA is currently citing this apparent lack of knowledge as a reason why it has been slow to develop guidelines to enable the operation of commercial, low altitude UAS. To some degree, the FAA is suppressing the development of this new industry as a response to the lack of credible information about UAS operations. It is the primary responsibility of the FAA to maintain the safety of the manned aviation industry, and without sufficient knowledge assessment of UAS technologies it cannot certify these systems.

If a change is not made to the US aviation planned adaptation model, then there is the potential that the UAS market could further be inhibited or that UAS may be adopted without the benefit of adaptive policies. However, even if the NTSB expands its investigative activities to UAS, there are serious doubts about whether the current method of planned adaption will work for the more rapid design cycle of UAS and the speed at which the industry is evolving. While learning from accidents may successfully inform and adapt commercial airliners which have a design cycle of 10 years and a lifespan of forty, the approach may not work for UAS which are conceived, built, operated, and made obsolete within a decade.

The model of planned adaptation has been successfully implemented in the US aviation industry for over forty years. It is likely the knowledge generated by the NTSB and the regulatory review and action taken by the FAA and other DoT agencies has resulted in the significant preservation of lives. However, based upon the serious questions raised above about the independent assessment capabilities, relevant processes and structure, and potential of the NTSB to handle new and challenging developments in aviation, it may be a reality that the model of planned adaptation in aviation… needs to be adapted itself.

8. Conclusion

Planned adaptation of regulatory policy has existed in United States aviation since the development of the independent National Transportation Safety Board (NTSB) in 1974. The mission of this Safety Board is to conduct unbiased, credible knowledge generation and assessment for the Federal Aviation Administration (FAA) and other DoT entities. By conducting investigations to determine the cause of aviation accidents, the NTSB provides valuable information to the aviation industry to inform change. The NTSB also delivers safety recommendations to the FAA which may support an update of existing policies or the establishment of new policies where necessary. Overall, the NTSB and FAA meet the criteria of planned adaptation by learning and consequently changing policy.

The success of the model of planned adaptation in the aviation sector was deconstructed and determined to be assisted by three enabling factors. First, the NTSB wielded the unique capability (compared to other knowledge generation organizations) of being able to increase the public awareness of safety issues without suffering repercussions from the regulatory agency or industry stakeholders. Second, the NTSB benefitted from the mandate to conduct knowledge assessment on a majority of aviation accidents in the United States. Unlike the National Research Council which is funded to conduct single studies on arbitrary bases, the NTSB is able to consistently conduct hundreds of related knowledge evaluations each year as accidents occur. Thirdly, the NTSB is able to enhance the planned adaptation model by advocating for safety changes which it believes are critical based upon the knowledge assessment it conducted. This final factor provides a mechanism for the NTSB to directly affect regulatory change despite the mood of the FAA.

While the success of the model of planned adaption in aviation appears noteworthy over the past forty years, the capability of the NTSB to continue knowledge assessment in the future is in question. A lack of adaptation of the NTSB procedures and techniques has placed the recommendations of the organization at risk of becoming irrelevant or biased by industry and the FAA. Furthermore, concerns over the capabilities of the NTSB to conduct investigations for the growing aviation sector have been expressed. Finally, it has been identified that without a change in the structure of planned adaptation in aviation, the current model will be unable to accommodate the rapidly growing sector of unmanned aerial systems.

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