Crisis Events as a Catalyst for Change in the US Air Transportation System — Implications for Capacity

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Abstract

Historically, aircraft accidents have preceded the implementation of many changes in the US Air Transportation System. These accidents act as catalytic events which generate awareness of a problem and pressure for change to occur. Specifically, aircraft accidents indicate the presence of safety problems. As past safety problems were addressed the frequency of accidents decreased causing new drivers for system change to emerge. Current drivers for change in the US Air Transportation System include increases in demand in the face of limited capacity, emerging requirements such as the need to address growing environmental concerns, and the need to replace and update aging system components. This paper explores the role of catalytic events in bringing change to the US Air Transportation System with a focus on the implications for capacity driven change. In order to address capacity constraints, infrastructure improvements, such as construction of new runways, or efficiency improvements, which would allow aircraft to be spaced closer together, can be made. However, changing the system in response to capacity can be difficult due to barriers posed by stakeholder conflicts and complex decision making and approval processes. The capacity problem, the need to address it, as well as the barriers to addressing it are presented in this paper. Finally, the paper explores the role of delays as catalytic capacity events and the likely actions following such an event.

1 Introduction

Historically, aircraft accidents have preceded the implementation of many changes in the US Air Transportation System. These accidents act as catalytic events which generate awareness of a problem and pressure for change to occur. Specifically, aircraft accidents indicate the presence of safety problems. As past safety problems were addressed the frequency of accidents decreased causing new drivers for system change to emerge.

Current challenges and drivers for change in the US Air Transportation System include increases in demand, emerging requirements, and the aging of system components. Demand for passenger and cargo travel has been growing since the creation of the system. Currently the growth of demand is outpacing the available system capacity causing delays and disruptions. Emerging requirements such as a need for increased security, the emergence of micro jets and unmanned aerial vehicles, growing fuel costs, and especially growing environmental considerations are putting pressure on the system. Finally aging infrastructure and a potential controller shortage also need to be addressed.

While the US Air Transportation system is facing substantial challenges, limited system capacity, in the face of continuously increasing demand for travel, poses one of the key threats to the continued operation of the system. Future increases in traffic levels are projected to outstrip current capacity in several key points of the system potentially causing significant disruptions. In response to this anticipated demand increase and other pressures, the Federal Aviation Administration (FAA) and the Joint Planning and Development Office (JPDO) are proposing projects to expand runway capacity and improve the efficiency of operations through new technologies and procedures.

In order to address these challenges, the US Air Transportation System will need to make significant changes, with lasting effects. However, the implementation of such changes faces barriers posed by stakeholder conflicts and complex decision making and approval processes.

The goal of this paper is to analyze examples of both safety and capacity system changes in order to better understand the role that catalytic events play in galvanizing a response to the capacity problem. While it is unclear what form capacity catalytic events will take, evidence exists that severe localized delays can act as catalysts for change. A case study of such a change at LaGuardia airport is presented and used the explore the likely responses to capacity catalytic events and the implications for the Air Transportation System.

2 The Role of Catalytic Events

In the US Air Transportation System, past changes were implemented predominantly in response to safety concerns. These changes were stimulated by catalytic events in the form of aircraft accidents. Table 1 shows examples of changes implemented in the US Air Transportation System following accidents.

The implementation of positive radar control shaped the current paradigm of air traffic control. Early controllers managed flights by talking on the phone with airline dispatchers, airway radio operators, and airport traffic controllers. In June 1956, however, a midair collision made it clear that this system was not scaling to safely keep pace with the growth of traffic. Two commercial aircraft requested, and were granted, a scenic detour into uncontrolled airspace over the Grand Canyon. Unfortunately, they did not see one another; the collision resulted into 120 deaths. The resulting outcry led to the hiring of 1400 new controllers, and the deployment of additional towers and navigational aids. Most notably, this led to the implementation of positive radar control. As part of this change radar were installed and all flight levels above 180 (18,000 feet) were designated as controlled airspace where aircraft would be monitored by air traffic controllers.

Although the implementation of radar increased safety, it did not entirely eliminate midair collisions. In 1986, a general aviation (GA) aircraft inadvertently strayed into the controlled airspace around Los Angeles International Airport (LAX); it collided with a commercial aircraft, resulting in 82 casualties, including 15 on the ground. Following this incident, the Traffic Collision Avoidance System (TCAS) was mandated. TCAS provides warnings to pilots of possible midair collisions. Today, TCAS also provides a back-up system for controllers during radar outages, allowing operations to safely continue rather than restricting flights in parts of the system while radars are fixed [1]

Controlled Flight into Terrain (CFIT), which occurs when perfectly operating aircraft are flown into ground or water, was also discovered and addressed following accidents. CFIT was one of the largest causes of aircraft accidents before it was addressed. An analysis of National Transportation Safety Board (NTSB) accident investigations provided

Catalytic Event	**Casualties**	**New System Capability**
Grand Canyon, AZ (June 30, 1956) Midair collision between two commercial aircraft in uncontrolled airspace over the Grand Canyon.	120	Positive Radar Control was implemented for all flight levels above 18,000, designating them as controlled airspace.
Los Cerritos, CA (August 31, 1986) Midair collision between a commercial and general aviation (GA) aircraft occurred above a residential neighborhood.	82	The Traffic Alert and Collision Avoidance System (TCAS) was developed and mandated by the FAA.
Dulles, VA (December 1, 1974) A Controlled Flight into Terrain (CFIT) accident of a Trans World Airlines jet occurred near Berryvilla VA while on approach to Dulles International Airport.	92	The Ground Proximity Warning System (GPWS) was mandated for use in all aircraft with more than 10 seats.
Cali, Colombia (December 20, 1995) A CFIT crash of an American Airlines jet near Buga Columbia while on approach to an airport in Cali Columbia.	159	Enhanced Ground Proximity Warning System (EGWPS) was mandated.
New York, NY (June 24, 1975) A rapidly evolving weather phenomenon called a microburst caused an Eastern Airlines jet to crash during a thunderstorm while on approach to John F. Kennedy International airport.	113	Low Level Windshear Alert System (LLWAS) was implemented at airports in regions with convective weather.
Charlotte, NC (July 2, 1994) A USAir jet crashed after encountering a miroburst while attempting to land at Charlotte-Douglas International Airport.	37	Terminal Doppler Weather Radar (TDWR) was installed at airports with microburst activity. The system provided significant improvement over LLWAS because it could detect the speed and direction of wind in a volume rather than just along the ground.

Table 1. Example Catalytic Events and the Resulting Changes

insight into the nature of the problem and allowed for a solution to be developed. The system, called the Ground Proximity Warning System (GPWS), provides warning to pilots when the distance between the aircraft and the ground below is too small. It was adopted by several airlines when it become certified. However, an accident was needed before that solution was mandated and implemented system wide. That accident occurred December 1974 near Dulles, Virginia when pilots unfamiliar with the terrain misunderstood a clearance given by controllers and descended too early. The Ground Proximity Warning System (GPWS) was mandated that same month.

Although the frequency of CFIT accidents decreased significantly after the implementation of GPWS, CFIT was still a major safety threat. The solution to the CFIT problem was updated in the 1990s following an accident at Cali, Colombia. The accident occurred because pilots entered incorrect data into the flight management computer and due to a miscommunication between pilots and controllers about which navigational aid was to be used. At this time progress in technology allowed for an Enhanced GPWS (EGPWS) which contained a database of terrain maps and could warn of potential CFIT crashes with terrain ahead of the aircraft and not only below.

A rapidly evolving weather phenomenon called a microburst can pose a large threat to arriving and departing aircraft. Microbursts create changes in wind direction that can reduce the lift experienced by an aircraft. If the aircraft is close to the ground, loss of lift can cause impact with the ground before pilots can recover. When accidents involving microbursts were first detected, there was a poor understanding of the phenomenon. Thus, an understanding of the weather pattern first needed to be developed. In this case both research programs as well as incremental implementations of increasingly better solutions were spurred by multiple accidents. The first of these solutions was the Low Level Windshear Alert System (LLWAS), implemented soon after a microburst crash in June 1975. Research programs and technical improvements continued through the 1980s. The crash of a US Air Jet in 1994 led to the installation of the Terminal Doppler Weather Radar (TDWR) at airports with common microburst activity. Since the implementation of TDWR, there have been no fatal accidents caused my microbursts at airports equipped with the technology.

These examples of past problems highlight a pattern of how changes are introduced into the US Air Transportation System. Problems in the system are defined by stakeholders and the first step to defining something as a problem is to know that it exists. Accidents provide a clear indication that something is amiss. In addition, accidents receive a significant amount of media attention spreading awareness of the event and potential system problems to the public. Such awareness causes pressure for change to occur.

Due to past successes at addressing safety concerns, the safety of the Air Transportation System has increased significantly since its inception. Figure 1 shows the trend in accidents between 1959 and 2003. It can be seen that the frequency of accidents both in the US and worldwide has decreased significantly making air transportation one of the safest ways to travel. Because of the significant improvements in system safety, safety catalytic events have decreased in frequency and instead other drivers for system change have emerged. However safety cases can be used to understand how change in the system occurs and what the pattern of change will be for emerging change drivers.

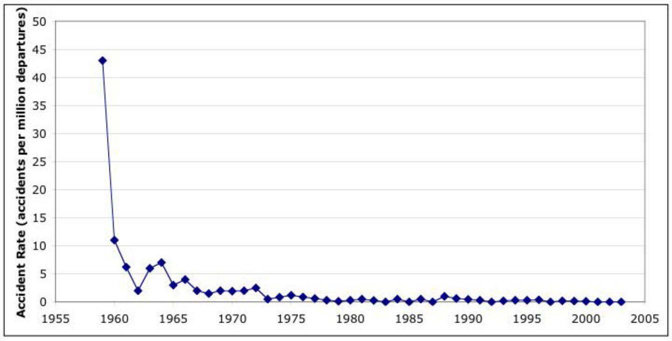

Figure 1. Accident Statistics [2]

3 Model of Change Processes in the US Air Transportation System

3.1 Model of Catalytic Impacts

Figure 2 shows a simplified version of the change process model. This model was developed based on a series of 13 case studies, concepts from control theory, and literature on policy adaptation a model of change processes in the US Air Transportation System was developed. The cases studied include those presented in the above section as well as those included in Table 2. These cases include successful and unsuccessful attempts to improve system safety, increase system capacity, and fundamentally change the operating paradigm of the system.

Boxes in the model represent high-level processes while arrows represent the resulting states. The Air Transportation System is represented as a process in the model, the output of which is system behavior. These outputs are monitored as part of the awareness building process, which is analogous to the concept of measurement in control theory. During the awareness building process, stakeholders develop and share an understanding and definition of the problem and potential solutions. This includes evaluating potential solutions by projecting future outcomes based on which solutions are implemented. Catalytic events play a significant role during this process. Such events highlight that a problem exists and spread awareness not only to the aviation stakeholders but also to the general public. It is the widespread awareness generated by these events that creates pressure for change [3]. This dynamic is highlighted in the model through the separate stakeholder vs. general public awareness states.

System Capability	Description	Status
Instrument Landing System (ILS)	Allowed safe landings during low visibility.	Implemented (1938)
Advanced Automation System (AAS)	Projected increases in demand required an upgrade in controller support tools to allow increased automation.	Failed (1994)
Microwave Landing System (MLS)	Plans to update ILS with a new technology.	Failed (1994)
Reduced Vertical Separation Minima	Need for added enroute capacity and international standardization led to RVSM.	Implemented (2005) after 23 years of delay.
Runway 14/32 at Boston Logan International Airport	Flight delays at Boston Logan Airport, particularly during north west winds, caused the Port Authority to seek another runway.	Implemented (2006) after over 30 years of delay.
Slot restrictions at LaGuardia Airport.	Attempt to remove slot restrictions at La Guardia airport caused sharp increases in delays resulting in an updated slot restriction plan.	Implemented (2000) and updated in (2007) as interim measures.
Automatic Dependant Surveillance-Broadcast (ADS-B)	Projected increases in demand require a change in the current paradigm of air traffic management.	Pending.

Table 2. Case Studies of Attempted Capacity Driven System Changes

Once awareness of a problem and potential solutions exists stakeholders engage in the change process. Here, stakeholders evaluate the projections for the future and develop preferences for action to be taken. Stakeholders then engage in a collective decision making process where the decision to address a problem is made and a solution is selected. Continuing the control theory analogy, this process is similar to a multiprocess controller.

Once a decision is made, it proceeds through the implementation process. Like an actuator in a control system, this is where the inputs to the system are adjusted. In this process, stakeholders allocate money, refine the details of the solution, and approve the chosen solutions.

3.2 Multi-Stakeholder Considerations and Barriers to Change

When the change process is successful, the capability of the system is improved and the problem being addressed is reduced or eliminated. However, barriers to change can arise in multiple places in the model and stall or even derail change efforts. In particular, the multi-stakeholder nature of the change process as well as the complexities of implementation can pose barriers to change. Figure 3 shows an expanded version of Figure 2. This figure includes the

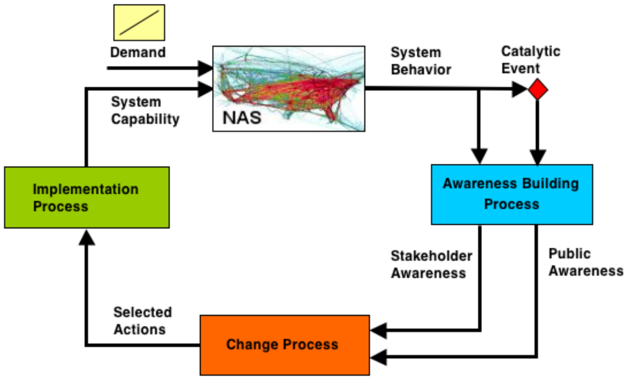

Figure 2. High Level Feedback Model of Change Processes

negotiation and solution refinement loops which capture the above mentioned barriers to change.

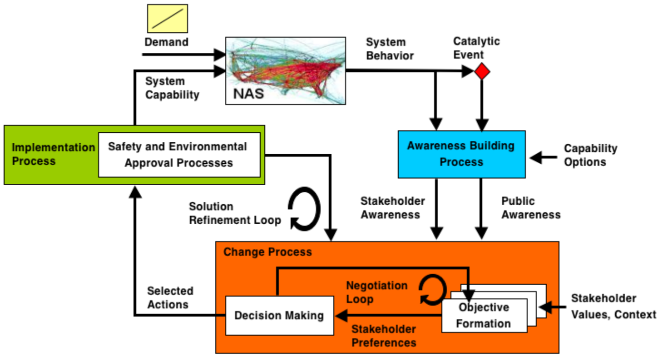

Figure 3. Feedback Model of Change Processes Illustrating Multi-stakeholder Dynamics

The negotiation loop occurs during the change process and captures the dynamics of decision selection in a situation with multiple stakeholders who have different agendas, value structures, and are effected differently by potential changes to the system. During this process stakeholders work to influence decision makers and interact with others to determine if concessions and agreements can be reached. Inability to overcome strong stakeholder oppositions can contribute to long time constants for bring about change.

Barriers can also arise during the implementation process. The complexities of determining the specifics of a solution as well as conducting the necessary safety, environmental, and other approval processes can delay change. In addition, stakeholder disputes can once again arise when details of a solution are being determined. Finally, the approval processes that occur during implementation can be deliberately used by stakeholders who are negatively effected by a change but were unable to influence decision makers against its implementation.

Catalytic events can help overcome the barriers to implementation by highlighting system problems and creating pressure for change. The remainder of the paper discusses the capacity constraints currently facing the US Air Transportation System, the barriers to implementing change in response to capacity drivers, as well as the potential catalytic events that can occur and what effect they will have.

4 Capacity Constraints as Drivers of System Change

As accidents have become less frequent, capacity constraints have emerged as one of the key issues driving the need to modernize the US Air Transportation System. The current crisis comes primarily from the continued increase in demand for air travel, as shown in Figure 4, and the limited runway space at major airports. Figure 4 shows the growth in revenue passenger miles, which represents growth of passenger travel, and freight ton miles, which represents the growth in aviation cargo. The result of growing demand and limited capacity are increasing delays, shown in Figure 5. The figure shows both monthly delays and a moving average. The moving average shows that delays peaked during the summer of 2001, but decreased following the attacks of 9/11 when demand for air travel and as a result the number of operations were significantly decreased. However, currently traffic has returned and surpassed the 2001 levels bringing with it a return of delays.

Expected future demand for air travel suggests that the problem of delays will continue to worsen. Because traffic is not evenly distributed over the US, as shown in Figure 6, capacity constraints and the resulting delays manifest primarily at busy airports during peak times. Delays at key airports, such as Newark International (EWR) or any of the other 70 airports that handle 90% of all flights [5], are a significant disruption to passengers and a financial burden to airlines. In addition, the cascading nature of delays can greatly amplify the effects of a disturbance at an airport—because aircraft are re-used for subsequent flights, the delay of one flight can delay all other flights involving that aircraft and the resources (e.g., gates) that it uses. For example, Figure 7 shows the effect that delays at Chicago O'Hare (ORD) had on the entire system in 2003. An approximately 8,000 minute increase in cumulative monthly delays at ORD, contributed to a 15,000 minute increase in national delays. As demand for air transportation outstrips

Figure 4. Growth of Demand for Air Travel in the US between 1970 and 2005 [4]

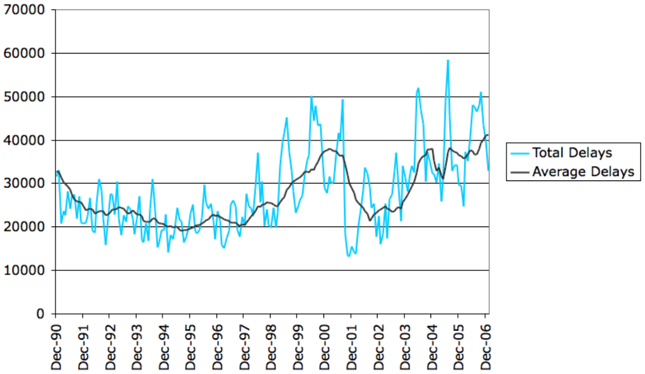

Figure 5. Growth of Delays in the US between 1995 and 2006 [5]

the available capacity, delays can disrupt or cripple operations, and if severe could have a negative impact on the US economy.

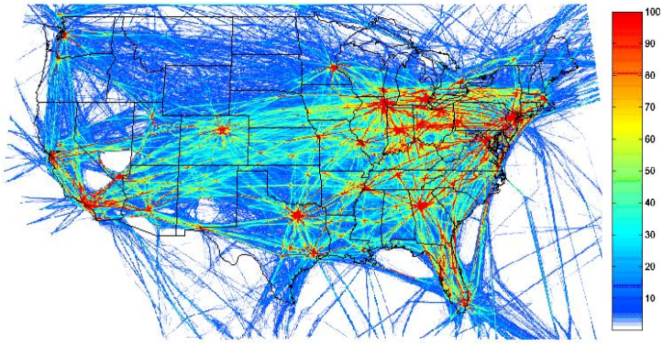

Figure 6. Density Map of Flights over the US (24 Hours of Traffic in January 2004) [6]

In order to address the capacity problem, three categories of solutions exist: increasing infrastructure, improving the efficiency of operations, and managing demand. Runway construction is an example of infrastructure expansion that creates more capacity at airports. Operational efficiency can be improved by reducing the spacing between aircraft both during departure and arrivals as well as enroute. An example of such a measure is the Reduced Vertical Separation Minima (RVSM), which was implemented for US domestic airspace in January 2005. Solutions in these first two categories expand the capability of the system to accommodate more flights. In contrast, the final category stems or stops the growth of demand to a level that the current system can handle. Current plans to modernize the US Air Transportation System include both infrastructure and efficiency improvements.

5 Barriers to Implementing Change to Address the Capacity Shortfall

Current plans to address the capacity shortfall include lengthening existing and constructing additional runways as well as implementing technologies and procedures to increase the efficiency of current operations. However, implementing change can be difficult and time consuming. The long time constants to enacting change stem from the complexities of the implementation process and stakeholder disputes about the impact of system changes. In addition, refining the details of a solution and conducting necessary approval processes can reengage stakeholder differences and be used by disenfranchised parties to deliberately block changes to the system. These dynamics are captured in Figure 3 in the negotiation and solution refinement loops.

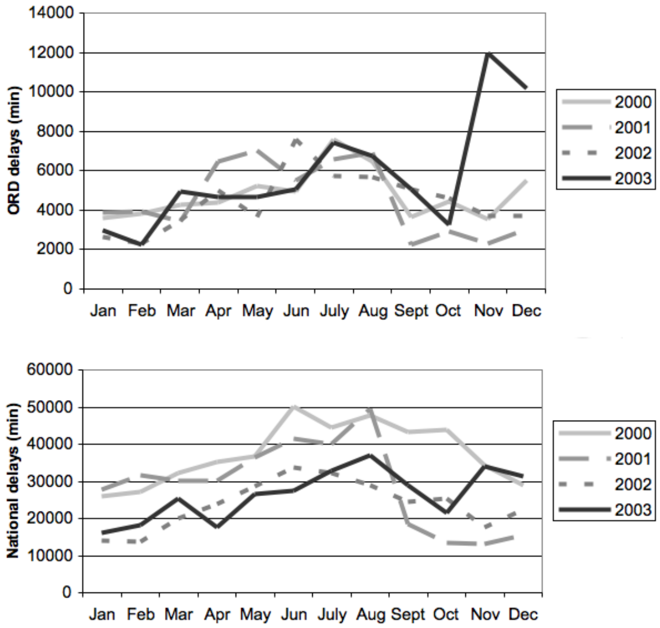

Figure 7. Effect of Delays at Chicago O'Hare in 2003 on National Delays [7]

5.1 Barriers to Adding Runway Capacity

One way of addressing the capacity problem is to expand or build additional runways at constrained airports. However, runway projects face strong opposition from local communities living around airports. These communities often feel that additional runways would result in additional operations which would negatively impact their quality of life by creating noise and pollution. These groups have successfully delayed or derailed many runway extension and construction projects through awareness building, lobbying, and litigation. As a result of these stakeholder differences, change can be stalled in the negotiation loop as parties cannot come to an agreement on how the capacity problem at an airport should be addressed.

If an action to build addition runways is selected either through negotiation or despite the opposition of community groups, such projects still take a significant amount of time to construct due to the complexity of the implementation process. Runway projects first require the allocation of funds and next need extensive planning. Once plans are made they need to comply with the environmental approval processes. In order to get approval for expansion projects, airports must comply with federal regulations and produce an Environmental Impact Statement (EIS) to identify the environmental impact of the project. In addition, similar state requirements need to be satisfied. Projects cannot be undertaken if the EIS and state environmental reviews are not approved. Once environmental approval is obtain local permits for construction also need to be obtained. Finally, contractors can be hired and construction can begin.

5.2 Deliberate Blocking of Runway Projects

If an action to build or extend a runway is selected despite stakeholder opposition, community groups can still fight the implementation of an expansion project during the solution refinement loop. Specifically, community groups use the environmental review process to block construction. Because projects need to pass through federal and state environmental review processes stakeholders opposing expansion projects can contest the EIS to block change. This can result in lengthy debates or litigation often surrounding the data and models used to estimate impacts of construction projects.

Blocking of change can significantly add to the implementation time constant. An extreme example is a runway opened at Boston Logan International Airport in November 2007. Due to litigation over the EIS and other permits the fight over the new runway continued for over 30 years [8]. While this example is that of the worst case scenario it illustrates how strong of an effect stakeholder disputes can have in bringing about change.

Even in non extreme cases extending or adding new runways is timeconsuming. A study conducted by the General Accounting Office surveyed the top 50 airports in the US. 92% of study participatns said that it was more difficult to balance envionmental concerns with airport operations than it was in 1989. 88% of the participants stated that the environmental review process contributed to delaying runway projects and 72% said that it was the primary cause of delay. The median time for an airport project amount the participating airports was 10 years [9], which while significantly less than the Boston runway is still too large an amount of time to respond to the pressure for change created by a catalytic event.

5.3 Barriers to Efficiency Improvements

Improving the efficiency of operations can help address capacity constraints by making it possible to space aircraft closer together to better utilize either runway, terminal area, or enroute airspace. Such improvements often require that airlines equip aircraft with addition technology. Since equipage costs can be high, if airlines do not see rapid benefits from equipage they can oppose changes that require them to invest in equipment. Such opposition once again causes delays to change during the stakeholder negotiation loop.

In addition to stakeholder differences, the complexities of the implementation process can also delay changes to the system. Any technology and procedure changes in the system need to be certified to meet safety standards. Proving safety can be a lengthy and difficult process that can take a substantial amount of resources, effort, and require numerous iterations of updating the capabilities and requirements of a solution. A large amount of analysis may be necessary in order to sufficiently prove that a system meets required safety performance, and in many cases limited operational implementations are used to understand safety consequences.

In cases where technology implementation is necessary to bring about system change, delays caused by stakeholders and by the complexity of the implementation process can render an attempted solution moot. The rapid pace of technology development means that it is entirely possible that the next generation solution will be developed and available before the existing solution can be implemented in the system. This may force stakeholders to decide to scrap a planned or partially implemented solution and try to begin again with the new technology. An example occurred with the implementation of datalink, a technology that would have allowed for a new way of transferring information for pilots to controllers. In this case communication standards changed 4 times and eventually implementation did not occur. The problem with such a strategy is that it can occur over and over as technology development progresses and the change process is restarted and delayed with each new development further adding to the overall time constant for change.

5.4 Deliberate Blocking of Efficiency Improvements

As in the runway cases, change can proceed even if not all stakeholders agree to it. Those stakeholders that feel they would lose significantly by the implementation of a proposed change have a large stake in continuing a fight even when a decision has been agreed on by others. Such stakeholders also usually do not have the ability to unilaterally change the decision. As a result, their objective becomes to get in the way of implementation in the hopes of preventing implementation or maybe restarting negotiations. In order to block change, stakeholders may use the safety review process as a way to stop change during the refinement loop. Because safety is such an important value in the system, stakeholders can very legitimately raise the question of whether a change will maintain the safety of the system. This question can block the progress of a change as it is difficult to prove that new technologies or procedures are truly "safe": In effect, stakeholders can exercise a "safety veto."

An example of the "safety veto" occurred during the implementation of a controller workstation upgrade called the Standard Terminal Automation Replacement System (STARS). The system was to be implemented starting in 1998; however, the Professional Airways System Specialists (PASS) questioned the safety of the technology interface and caused a $460 million increase in costs and a 4 year delay in the start of implementation [10]. The safety of the technology was questioned at the same time as the PASS union was renegotiating their labor contract [11].

Given the difficulties and delays facing the implementation of change in response to capacity problems, what enablers exist to help make significant change possible and timely?

6 Example of Catalytic Like Capacity Event

In the case of safety problems, accidents have provided the necessary public pressure to overcome stakeholder disputes and implement change. It can be expected that capacity catalytic events would also provide a rapid change, but it is not clear what a capacity event is. Delays are an obvious symptom of capacity constraints but, because they increase slowly and can cycle with seasons, they do not necessarily raise public pressure. However, a problem that causes extreme delays, such as those that occurred at LaGuardia (LGA) following the removal of slot restrictions in 2000, can result in significant pressure and a rapid reaction to remedy the problem.

The case of LGA provides an interesting case study of what a capacity catalytic event may be. LGA is one of the four slot restricted airports in the US, which means that the number of operations at the airport is capped thereby managing demand. The restrictions were first implemented in 1968 in response to congestion problems [12]. The initial plan was to impose the restrictions for one year until a better solution could be identified and implemented. However, in 1969 the restrictions were extended until 1970, than again until 1973. In 1973, when a better solution was still not identified, it was decided that the slot restrictions would remain in place indefinitely [13].

The next decision regarding slot restrictions at LaGuardia did not occur until the passage of the AIR-21 Act in 2000. With the goal of further deregulation and making increased competition possible, the act announced that slot restrictions would be removed at the airport in 2007 and that exemptions to current limits would be immediately granted to certain operators [13]. Following the implementation of exemptions, the demand for the airport increased to about double the capacity of the airport as shown in Figure 8. The result of this increase was a rapid growth in both departure and arrival delays. Figure 9 shows that average delays per aircraft reached 80 to 90 minutes for both departures and arrivals. At one point in this period, delays from LaGuardia accounted for 25% of all delays in the nation. This rapid increase in delays and a 1.5 hour average delay per aircraft acted as a catalytic event requiring change. However, it is important to note that this case is unique in that it was artificially caused by the decision of Congress to remove slot restrictions at LaGuardia.

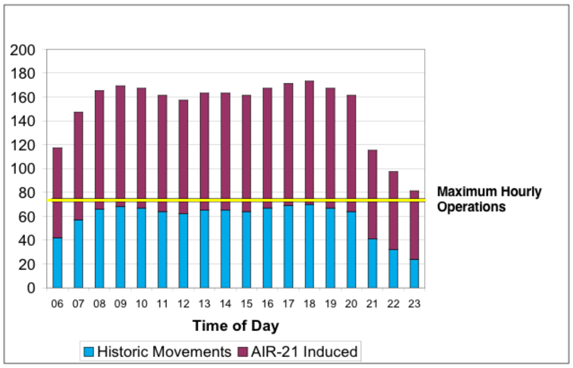

Figure 8. LaGuardia Scheduled Operations Following Slot Exemptions [14]

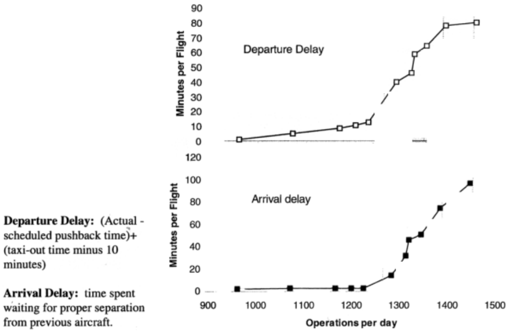

Figure 9. LaGuardia Delays Following Slot Exemptions [14]

7 Short Term Response - Demand Management

In response to the rapid increase in delays, the Port Authority of New York and New Jersey, the operator of LaGuardia, quickly moved to reinstate caps on the number of flights allowed. The moratorium on additional flights was implemented on September 19, 2000. While this move was not strictly within their authority, it was soon backed by the FAA and received support from the public and local Congressional representatives [15]. The FAA showed support by officially limiting the number of slot exemptions offered at LGA [13].

Intervention on the part of the Port Authority and the FAA was necessary due to the incentives for airline behavior. Following the initial passage of AIR-21, airlines wanted to take advantage of the latent (but until then unaccessible) demand for additional flights to and from LaGaurdia. However, leaving allocation of resources at the airport to the airlines resulted in a commons problem where each airline stood to benefit by adding flights, even if it was ultimately to everyone's detriment. In addition, even once it became clear that action to reduce the number of flights would have to be taken, airlines had the incentive to continue adding flights in anticipation of that slots would be reinstated and assigned, at least in part, based on who already held them.

The actions taken by the Port Authority and the FAA, reinstated, in a slightly new incarnation, the slot restrictions at LGA. The capping of traffic was followed by a string of actions similar to those taken in the 1960s and 1970s. When the FAA responded to the NY Port Authority's moratorium on additional flights it capped the number of exceptions at 159. This cap was to be temporary and last about 9 months. However, the cap was extended 4 times until a new cap of 75 flight per hour was announced in August 2006 and went into effect January 1, 2007. The reason for extending the initial emergency cap was to allow for the solution refinement loop to take place. Stakeholders lobbied the FAA to influence the final rule and especially how the available slots would be parceled out to airlines. Time could be allowed for this because a temporary solution was already in place and because the attacks of 9/11/2001 reduced demand.

The case of LGA illustrated both what a crisis event in capacity may be and also the actions that can be expected following it. When a catalytic event generates pressure for change decision makers needs to act rapidly to address the problem. Because of the long time constants of building new infrastructure and proving the safety of large scale technology or procedural changes a faster solution becomes necessary. When rapid action is required, demand management, which can be implemented in days rather than years, becomes the likeliest solution. Demand management restricts the growth of demand instead of implementing new system capability, as shown in Figure 10.

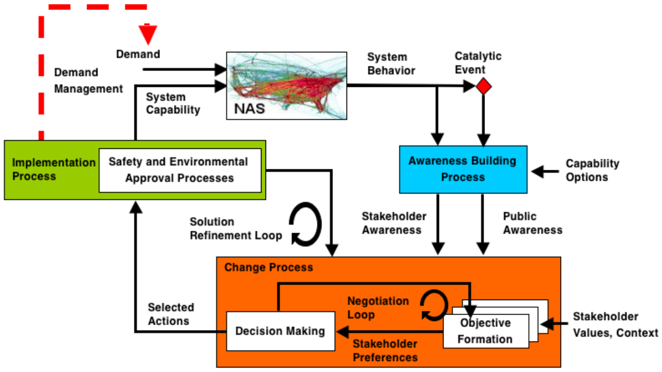

Figure 10. Demand Management

8 Conclusions

As demand for air travel continues to grow the US Air Transportation System will become less robust to interruptions and capacity crisis events are likely to occur. In addition, such events are likely to increase in frequency as demand continues to increase. These events will occur at busy airports around the country and will act as a catalyst for rapid change to address the capacity problem. Past examples of catalytic events in safety as well as the example of LGA suggest that once pressure for change exists the implementation of demand management becomes a likely reaction to capacity catalytic events. However, the current edition of the Next Generation Air Transportation System plan does not include any discussion of demand management [16]. The localized manifestation of the problem as well as the lack of planning for demand management creates the risk of developing a haphazard and complex system of restrictions that may be suboptimal for the system as a whole. There are a number of possible options to prepare for this situation. The first is to plan for the implementation of demand management so that it can be implemented in the most beneficial way. The second is to investigate alternative methods of generating awareness and pressure for solving the capacity shortfall. Such pressure, if sustained, would allow for the expansion of capacity to accommodate growing demand. Finally, in addition to implementing demand management decision makers can use the momentum generated by catalytic events to set in motion longer term plans for addressing capacity needs.

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