Tomorrow's Air Traffic Control System: Less safe and more costly for consumers?

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Introduction

Air transportation impacts economic growth by enabling access to markets, people, capital, ideas and knowledge, labor supply, skills, opportunity, and resources (Ishutkina & Hansman, 2008). The economy's contribution in turn is the provision of capital, which generates greater demand for passenger and freight travel. The figures associated with air transportation's economic contribution are remarkable. For example, beyond the generation of 32 million jobs annually that it maintains, air transportation is a major facilitator of global trade, with some estimates placing the total value of goods transported representing 35% of all international trade. Since its inception, it has been increasingly recognized as a fundamental pillar of global society, as indispensable to our daily lives as medicine and telecommunications, and essential for social progress and economic prosperity. A critical component of the air transportation system is air traffic control (ATC); a service that employs advanced state-of-the-art surveillance and communication technologies to ensure the safe passage of aircraft from one point to another. Air traffic controllers are the human operators tasked with performing this job and their employment is critical to the continued provision of ATC service.

Air Traffic Control as a Service

Historically the 'service' of ATC has been conceptualized in terms of safety. This tendency is not without merit. ATC was born as early as 1929 over concerns regarding the safety of an increasing number of aircraft using the national airspace system. These concerns proved to be warranted in 1956 when two aircraft collided over the Grand Canyon, prompting the United States Congress to invest in safety. For the average passenger today, the procurement of transportation services from an airline is likely to occur only if there is a 'reasonable' assurance of safe passage from origin to destination. While the idea of what is 'reasonable' may vary greatly from one passenger to the next, generally speaking safety is conceptualized as a dichotomous state (either a particular aircraft will crash or it will not) and the overwhelming majority of aircraft reach their destination without serious issue. Consequently, stakeholders who have a vested interest in the air transportation system have increasingly moved beyond viewing safety as being the only service of interest. And rightly so it may be argued. After all, the safest airline in the world is one that does not fly at all. If an airline does not fly, it is not profitable. Hence, a tradeoff exists between financial viability of an air carrier and safety associated with increased transportation frequency. At the same time, increased trip frequency at the expense of marginal decreases in safety may be unacceptable if the flights are not being completed in a manner that is cost efficient to the operator, or time efficient from the perspective of the passenger. Hence when considering the 'service' of ATC, it is important to view it as a multidimensional concept, that is a) subject to interpretation based on the perspective of the stakeholder, and b) likely to impact other services of interest.

Naturally, this raises the question of what a 'service' is. Our definition is drawn directly from Appendix D of the Global Air Traffic Management Operational Concept, Doc 9854), which provides an overview of a variety of service expectations that stakeholders of the air traffic system may have; services that include safety efficiency, flexibility, predictability, access, capacity and more. It is equally important to determine the role that ATC workforce plays in service provision, within the context of commercial air transportation.

The Controller Workforce, Service Provision & Evolution

The provision of ATC services is ultimately the responsibility of the controller. Through classroom and on-the-job training, controllers are taught and ultimately master the art of air traffic management. This forms the basis for the provision of the *safety* service, whereby controllers work to ensure aircraft are separated from one another. However, beyond safety, a controller also works to ensure that the routing provided to an aircraft is *efficient* (within the constraints of the environment). Inefficiency has financial implications, in terms of added fuel and labor costs for air carriers, as well as workload implications for the controller and hence it is kept to a minimum. Often controllers will try to provide direct routing instructions to aircraft in order to maximize the efficiency of airspace movement. At the same time, controllers will also work to ensure that aircraft requests for flexibility (e.g., flight level changes to minimize fuel burn) can be accommodated. However, the provision of services beyond safety to a single aircraft will be accommodated to the extent that it does not impede upon basic service provision to other aircraft. A failure to do so inevitably results in delay.

Delay has many disadvantages. It is costly for the airlines (e.g. in terms of fuel, personnel overtime, passenger discomfort, missed connecting flights, luggage delays), and for controllers (e.g., in terms of increased workload as a result of traffic peaks and reductions in traffic structure predictability). In the United States alone, nearly 15,000 controllers work 24 meticulously to keep one of the most complex and sought after air transportation systems open for business by minimizing delay. To suggest that this system plays an important role in fostering trade belittles its true economic contribution. For example, in 2008, US air travellers spent almost $250 billion on goods and services, and freight valued at over $562 billion was transported domestically and internationally (FAA, 2010). The same report found that in 2009, air carriers operating in U.S. airspace transported 793 million passengers over 1,039.3 billion revenue passenger miles (RPM), and 53 billion revenue ton-miles of scheduled freight passed through U.S. airports. The air traffic controller workforce plays a critical role in supporting this type of economic activity.

And this workforce is evolving. At a high level, the nature of this evolution can be understood within the context of global aging, a phenomenon characterized by the greying of the world's population (Andreev & Vaupel, 2005; U.S. Census Bureau, 2004). This effect is largely the result of declining fertility rates and increasing longevity. Longevity may be seen as a human success story—the triumph of public health, medical advancements, and economic development over diseases and injuries that had limited human life expectancy for millennia (Kinsella & Philips, 2005). But longevity in the face of declining fertility has brought about its own set of challenges. While the United Nations has acknowledged the related challenges that impact family sustainability and provision of services *to* aging populations, relatively unexplored is the question of how an aging population *impacts* the provision of services. In safety critical domains, such as ATC, this question is especially pertinent. At first glance, increasing longevity suggests, a) an older controller workforce currently providing services, b) the prospect of eventual retirement of this group, and c) the need to replace when necessary this population with young qualified recruits. Global aging has thrust upon governments the need to address these concerns sooner rather than later. Doing so requires an analysis of the extent to which the first two considerations are true.

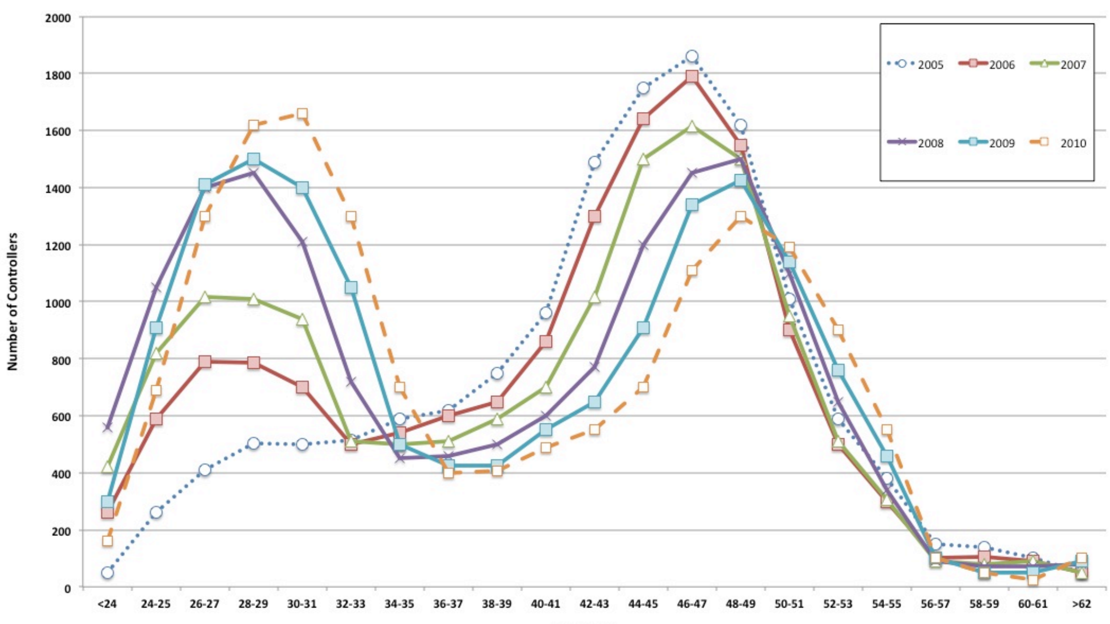

Figure 1: Demographical profile of U.S. controller workforce

In the present paper, these issues are explored within the context of the U.S. air traffic controller workforce. Figure 1 provides an overview of the demographical breakdown of this workforce from 2005 to 2011, specifically depicting the age distribution of subsections of this population. In viewing the graph, two trends stand out clearly, both of which conform to the assumptions associated with longevity. Firstly, there is a prevalence of an older controller population, peaking at around 1800 bodies, in the late 40s age range that gradually reduces in size from 2005 – 2011. Secondly, this distribution changes significantly as older controllers begin to retire and there is a sharp increase in the number of new controllers hired into the workforce. The rate of this increase must be considered on two levels. Firstly, the reason for the hiring surge corresponds to concerns over an impending staffing crisis in the workforce that has the potential to negatively impact the provision of air traffic services. The FAA staffing crisis has most directly been related to the massive influx of new controllers that were hired by the agency after the strike of 1981. Being the mandatory retirement age for controllers is 56, it would be expected that the FAA would have began hiring controllers to replace its aging workforce prior to them retiring; but the FAA did not begin hiring large numbers of new controllers until 2006 (Dionisio, 2010). The net result is the new controller hiring spikes seen in Figure 1.

The second implication of the hiring of new controllers is most directly related to service provision. New controllers are brought into the system is to ensure continuity of service and to minimize any disruption to air traffic services as a result of older controller retirement. The reason for this is clear. Low staffing levels can have a threefold effect on air traffic controllers including increased overtime, combined positions and increased training, all of which can lead to fatigue and cause stress on the qualified portion of the workforce (Dionisio, 2010). In the short term, this can result in safety being compromised, as has been demonstrated through numerous events. For example, near misses between aircraft, caused as a result of staffing shortages across Russia, Australia, South Africa, and the United States, are getting close to becoming midair disasters, and in some cases airlines are being forced to choose between canceling, delaying, or diverting flights, or having loaded jetliners flying through uncontrolled airspace (Baguley, 2008). In the longer term, because of the close relationship between economic growth and the air transportation industry, a country's economy can be negatively affected by a disruption in ATC service provision as a result of controller shortages.

To address this, many ANSPs (like the FAA) have started rapid hiring of new controllers to replace those scheduled for retirement. The premise behind this hiring process is that by replacing a retiring controller with a new one, the disruption in the provision of air traffic services to the users of the system is minimal. Further, because it is not just a single service of interest to airspace users, but rather a range of services that has been described earlier in the paper, a fundamental question is raised: how is the evolution of the workforce likely to impact the provision of ***services*** of interest to users of the air transportation system? More specifically, is there a qualitative performance difference in terms of ***service provision*** between older experienced controllers and younger novice controllers?

Challenges of Predicting Service Provision with a Changing Workforce

Answering this question is a challenge for two reasons. Firstly, from a research perspective, ATC has not received treatment as a multidimensional service. More often than not, investigations into workforce issues focus squarely on the issue of safety. The focus on safety is important but as previous noted, not adequate because safety as a service cannot be and certainly is not the only issue stakeholders consider when making operational decisions. Even in the area of safety, it is important to note that the public tolerance for adverse outcomes due to workforce errors depends in part on the perception of risk, which is influenced by perceived control and lethality. Because the number of safety events relative to the number of operations conducted is miniscule (e.g., the National Transportation Safety Board currently estimates that over 95% of aviation incidents will culminate without any loss of life), adequately conveying the seriousness of safety risk can be difficult. The second reason is that even when other services are considered, researchers often have a difficult time specifying metrics that may be of interest to *different* stakeholders. For example, efficiency can be thought of as being the 'path of least resistance' an aircraft follows from an entry point in a sector to the exit point, based on ATC instructions. Hence, total distance traversed or time spent in the sector represent good metrics to rely on when calculating route efficiency. But efficiency may also be represented as the number of communications it takes a controller per aircraft to manage a region of airspace. In this instance, it is the efficiency of controller performance, which is being considered versus the efficiency of a single aircraft's movement. Considering this view affords researchers to examine tradeoffs both within and across different services when looking at the value of service expectation provision by the workforce.

The following section addresses both of these issues in two ways. Firstly, the service of safety is examined through an analysis of safety events that have occurred in the US National Airspace system from 2008 – 2010. In addition, laboratory studies have been reviewed and their findings extrapolated to determine the collective implications on safety. Secondly, the applicability of other studies is reviewed and their findings extrapolated to determine how an evolving workforce impacts other services of interest to stakeholders (e.g., efficiency).

Analysis of Safety Service Provision

The analysis of safety service provision was conducted by reviewing over 7173 event reports entered into safety reporting systems (e.g., ASIAS), which occurred during the 2009 calendar year. For each event reported, the age/experience level of each controller was recorded to create a workforce risk estimate (broken down by experience level) of the entire controller workforce involved in safety events during the aforementioned time period. The result for each experience was then converted into proportions relative to the total number of controllers included in the analysis sample (Total N=7173). The end result is a workforce-based risk estimate, which is representative of the "likelihood' of involvement in an error based on the chronological profile of the controller (see Broach, 1999; Broach & Dollar, 2003, CNAC, 1995). These proportions were then plotted against the proportion of controllers (broken down by experience) in the workforce at around the time the safety events were reported (Total N=15653). By illustrating both distributions side by side, it is possible to get sense of safety risk susceptibility across the entire workforce, based on the experience level of the controller.

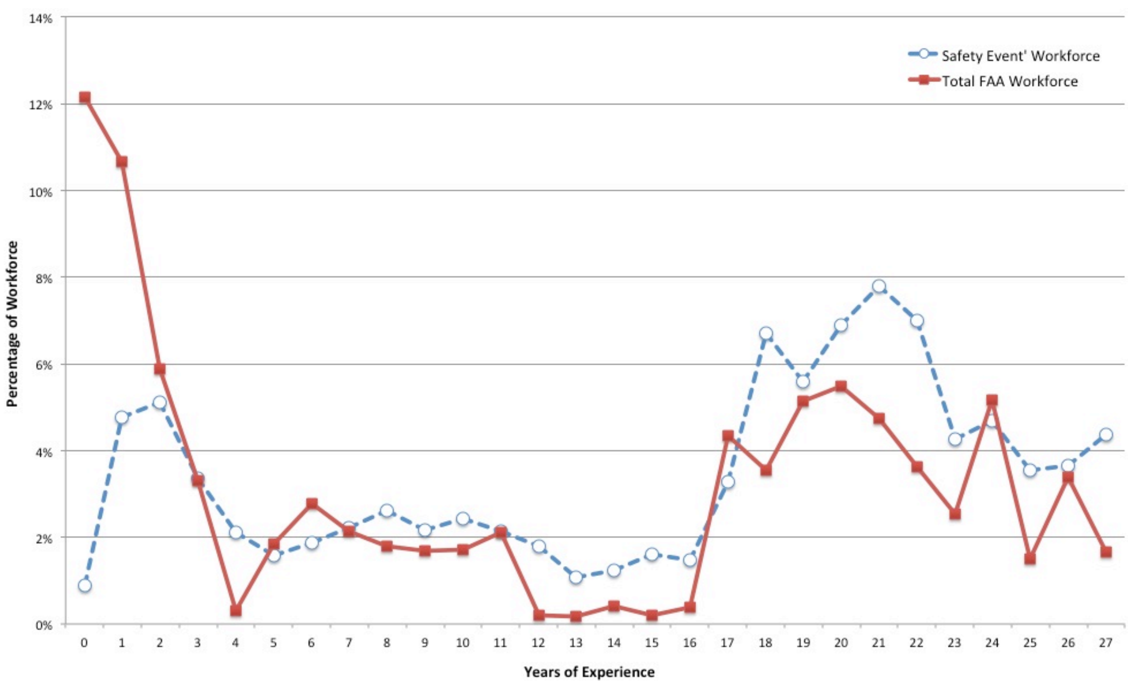

Figure 2: Safety event distribution of sample controllers plotted against total controllers in FAA workforce (2009)

The resulting distribution (Fig. 2) shows three clear patterns. *Firstly*, the distribution of the total FAA workforce is largely binomial. There are two clear spikes in the data set, first for controllers who have less than four years on the job, and the second for controllers who have between 17 and 25 years of experience. The former corresponds largely to recent rapid hiring initiatives conducted by the FAA to compensate for projected controller retirement; this retirement is associated with hiring in the early 1980's (which is clearly illustrated by the second distribution spike). *Secondly*, the distribution of safety events from the sample workforce data set also appears to be binomial, with younger inexperienced (with less than four years of experience) and older more experienced controllers (who possess between 17 and 25 years of experience) showing greater involvement in these events compared to the mid-range of the population.

Thirdly, younger inexperienced controllers appear to be greatly underrepresented in the sample whereas older more experienced controllers appear to be slightly underrepresented[1].

Interpretation of these results must be considered from the perspective of workforce implications. Firstly, the elevated safety error rates amongst younger controllers is hardly surprising; this given that youth is often associated with inexperience, the negative effects of which gradually decline as greater familiarity is acquired on the job. Such a supposition is consistent, not only with the general expertise literature, but more specifically with empirical investigations examining controller performance based on experience. For example, Nunes & Kramer (2009) found that across a range of conflict detection, conflict resolution, and airspace management tasks, novice controllers exhibited significantly higher error rates compared to their older, more experienced counterparts. Conversely, higher safety event rates, like those seen in Figure 2, amongst older controllers have historically been associated with underlying cognitive decline in basic functioning. Ironically, it is concerns over this type of decline that formed the basis for mandatory retirement policies that were enacted by Congress. However, empirical investigations by researchers over the last few decades have begun to consistently challenge assumptions of age-related performance impairments amongst controllers (Bisseret, 1970; 1981; Donohoe, Lamoureux, Atkinson, Kirwan, Phillips & Brown, 1999; Reddng & Seamster, 1993). Of particular note are studies that have either highlighted no negative age-related safety occurrences (Broach & Schroeder, 2006; Nunes & Kramer, 2009) amongst older controllers who have high levels of expertise on the job. This raises the question of why elevated safety event rates are being observed in the current data sample.

One plausible explanation is related to how controllers are populated across specific facilities in the United States. While all ATC facilities are considered important to the provision of air transportation services, a subset of these facilities are considered to be 'critical.' This characterization is based on economic contributions, number of operations and user demand. An investigation into ATC staffing levels has revealed that these critical facilities contain higher levels of older, more experienced controllers compared to the national average (OIG, 2012). Specifically, 32% of controllers at these facilities are retirement eligible (i.e. older/more experienced) compared to the national average of 25%. These controllers have greater levels of exposure to traffic patterns that are denser, more complex, and more voluminous and operate under more stringent restrictions. This exposure is a critical variable in assessing the risk for the occurrence of an adverse event (Broach & Schroeder, 2006). For example, a controller working a busy, low-altitude transitional sector with multiple merging airways that feed a major hub during an afternoon rush will have a greater opportunity to commit an OE than another controller working a high-altitude sector with sparse cross-continental traffic in steady, predictable east/west flows (Broach & Schroeder, 2006). Hence, it is entirely plausible that the increased rate of safety events amongst older controllers is the result of increased exposure to risk-contributing variables at critical ATC facilities. Such an explanation is congruent with recent findings of age-related performance sparing by researchers[2].

Analysis of Efficiency Service Provision

Beyond ensuring safety, there is a requirement to provide efficient service. Although often conceptualized as being the quickest route an aircraft may traverse in a sector, it has been noted previously that the concept of efficiency can vary, depending on the perspective of the stakeholder in question. Relevant to the present paper is the issue of how the provision of efficiency is likely to change as the ATC workforce evolves. A study by Nunes & Kramer (2009) examined this issue within the framework of ATC tasks that were made increasing more complex. In the study, controllers with varying levels of experience were asked to perform a series of conflict resolution, aircraft sequencing and airspace management tasks. On the conflict resolution task, controllers were asked to provide control instructions to aircraft that were on a converging path. Researchers found that despite near uniformity between the controller groups on whether or not a conflict was resolved, there was a stark difference regarding how the conflict was resolved. Younger controllers issued more extreme altitude commands to resolve the situation, compared to older more experienced controllers. Simply put, the benefits of experience appeared to manifest themselves in terms of deviation efficiency (i.e. how far off course an aircraft is taken); such a metric can readily be translated into cost for the air carriers. A different type of efficiency benefit was also observed based on experience, when controllers were asked to perform a more complex airspace management task. In this task,

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[1] In interpreting this data set, we assume that all controllers have an equal opportunity to report safety events.

[2] We note that the extent to which experience may mitigate the effects of exposure to risk-contributing variables is unclear and warrants further investigation.

they used a combination of control instructions and flight strips to safely manage the flow of aircraft in a region of airspace for 60 minutes. The analysis revealed that although the number of aircraft handled was roughly equivalent between groups, older more experienced controllers were able to achieve this by issuing far fewer control instructions to pilots compared to their younger counterparts. This suggests that domain relevant knowledge may also exhibit itself in the form of 'cognitive efficiency.' The absence of such efficiency amongst younger controllers may translate to a reduced ability to handle abnormal events.

Conclusion

The air transportation system has a crucial role in fostering trade and making any place on the globe easily and quickly accessible. This system is reliant on a highly skilled air traffic controller workforce. The present paper sought to examine how an evolving workforce may impact air transportation service provision, by looking at safety and efficiency tradeoffs based on a controller's demographical profile. Our analysis reveals that from the perspective of safety, a combination of disproportionate older controller retirement coupled with the inexperience of younger controllers is likely to result in elevated safety event occurrence. Financially speaking, workforce evolution may also result in increased cost for airlines, as one byproduct of inexperience appears to be suboptimal decision making, which impacts the provision of efficient control services by ATC. In the short term, technology can be implemented to counteract some of these effects. This is certainly the premise behind various NEXTGEN initiatives. From Data Communication to Staffed Virtual Towers to System Wide Information Management, there appears to be no shortage of technological proposals aimed at improving safety and reducing cost for users of the air transportation system. Yet, the controller remains integral to the sustained functioning. Hence, further research is required to more intricately examine tradeoffs in service provision based on demographical changes. After all, an ATC system can be safe and highly efficient as a system, but its users will not think so if the service it provides is not the service they need (Hopkins, 1995).

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