The Limits of Arrival Rate: You Can't Have It Both Ways

An Exhaustless Inc. White Paper

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Transportation Secretary Elaine Chao and other department officials frequently present information about key projects at industry meetings and when testifying to Congress. We must call attention to a costly misunderstanding about the potential benefits of precision navigation, or NextGen. The problem is that the concepts of 'variability' and 'capacity' are being confused. This misunderstanding is often made in evaluating processes, but it could have significant consequences to the magnitude of flight delays.

The claim is that if aircraft could use precision navigation, it would reduce their spacing on arrival and increase the landing rate at airports. However, that is not possible. Let us explain why.

In Queueing Theory, the equilibrium delay in a service is described by the Pollaczek–Khinchine (P-K) formula[1]:

$$delay \approx time_{landing}\, x\, \frac{utilization}{1-utilization}\, x\, \frac{(Var^2_{landing\ time} + Var^2_{arrival\ to\ queue})}{2}$$

In words, delays = time it takes to land * utilization/(1-utilization) * average (variability of time it takes to land + variability in arrival times to the landing queue). As you can see, longer landing times would create longer delays. Higher utilization of the landing air space would also increase delays. Most people are familiar with waiting in a long line for a slow service. However, high variation in the service time or in the rate of arrival to the queue also leads to longer delays.

Let's look at the components in the formula relative to NextGen:

Variability

To reduce delays, reduce the variability of arrival time to the landing queue.

NextGen reduces this variability by using precision navigation to tightly choreograph separation during landings, and higher-order math to rearrange the queue when unscheduled flights arrive. This increases the slack, allowing the queue to gracefully absorb randomness and thus reduce delays, but only if both the overall rate of arrivals and the utilization are held constant.

[1] Hopp and Spearman (1996)

To reduce delays, reduce the variability of landing time.

Landing time is comprised of three separate processes: time for the wake ahead of you to dissipate, time to descend, and time to exit the runway. Current operations make ongoing improvements to reduce this variability, such as grouping similar airplanes together in the queue. NextGen does not impact the variability of any of these processes.

Landing time:

To reduce delays, reduce the time it takes to land.

To reduce landing time, you must reduce the runway occupancy time, the wake dissipation time, the descent time, or some combination of these. The combined duration of these three processes must be reduced to reduce overall landing time.[2]. NextGen does not impact these processes.

This is where the mix-up comes in: The increased slack from the reduced variability of arrival time is misinterpreted as 'reduced time to land'. If this mistake continues, the FAA/ATC's will reduce the spacing between flights to increase the rate of landings, utilization will start to approach 1, and the delays will grow *exponentially*. This will happen because the closer spacing will increase the chances that a landing does not leave the runway in time for the following flight, leading to more go-around maneuvers. With a full arrival-queue of aircraft, there is no slack available to insert the out-of-schedule landing that was forced to go around. This lack of slack leads to increasingly larger, unbounded delays as utilization increases.

Utilization

To reduce delays, reduce the utilization.

There are two ways to reduce utilization[3]: by increasing flight capacity[4] or by decreasing the arrival rate[5] to the landing queue. NextGen does not impact either of these elements.

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[2] The Exhaustless landing technology is the only solution that reduces both the runway exit time and the wake dissipation time. https://www.google.com/patents/US9079671

[3] Kleinrock (1975)

[4] The Exhaustless technologies work together to create both takeoff and landing capacity. https://www.google.com/patents/US9156564

[5] The Exhaustless Congestion-Prevention Management Service decreases the arrival rate by reducing peak-demand flights using congestion-prevention pricing.

Conclusion

As you can see after reviewing each of the elements of the P-K formula, precision navigation will not increase flight capacity or reduce utilization. Additionally, the GAO[6] and the National Academies[7] have all *stated* that they do not expect increased flight capacity from NextGen. And the data from the Houston[8] NextGen implementation shows that the benefit is negligible to passengers. But we still support the implementation of precision navigation because it will reduce the variability of arrival time.

So, we agree that airlines should add precision navigation to avionics to utilize the full functionality of NextGen. This will increase the slack and reduce delays. But don't confuse that with increased capacity. You can't have it both ways.

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[6] See testimony of Gerald Dillingham, PhD, Director of Physical Infrastructure Issues for U.S. Government Accountability Office at the Hearing before the House of Representatives' Subcommittee on Aviation, 113th Congress, June 18, 2014.

[7] http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=21721

[8] https://www.faa.gov/nextgen/snapshots/metroplexes/?locationId=9