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Is access to general aviation airports with precision approach and no instrument landing systems a club good? A study of six airports☆

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ABSTRACT

Access to general aviation (GA) airports can generally be viewed as non-excludable and non-rivalrous. However, access to GA airports using lateral vertical guidance (LPV/LP) and no instrument landing systems (ILS) will exclude aircraft operators not equipped to take advantage of satellite navigation, thus transforming access into a club good. Extending access to GA airports through satellite navigation is an important aviation issue at a time when air traffic service providers are transitioning from a radar- to a satellite-based air traffic managed system. The provision of access to GA airports with precision approach and no ILS as a club good may require a change in the level of service that emphasizes service priority to the aircraft capable of taking advantage of satellite navigation as opposed to a first-come, first-served queue management.

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1. Introduction

This article focuses on general aviation (GA) airports that enable precision approaches using Localizer Performance with Vertical Guidance (LPV) and without Vertical Guidance (LP) when there is no Instrument Landing System (ILS). For convenience, we will refer to this type of airport as GA airport with precision approach. As of April 2013, there were 3100 new Wide Area Augmentation System (WAAS) LPV and 414 LP approach procedures, according to the Federal Aviation Administration (FAA).[1]

Before outlining the attributes of the LPV and LP approaches, it is important to define 'general aviation' and 'general aviation airports'. General aviation flights are usually operated under 14 CFR (Code of Federal Regulations) 91 Subpart K (on-demand fractional ownership flights) and Part 135 (commuter and air taxi operations[2]). In this study, a GA airport refers to a facility where itinerant and local GA aircraft represent at least 50% of the total operations (takeoffs and landings) based on FAA's OPSNET data.

GA airports play a significant role in the National Airspace System (NAS) and in the U.S. economic activities. They, not only provide critical access to smaller communities, but also support commercial activities necessary for manufacturing and distribution, emergency preparedness and response, as well as training for pilots, among many other benefits. According to the FAA's Economic Impact of Civil Aviation in the U.S. Economy (2011:22), "general aviation operations contributed $38.8 billion to total output. Factoring in manufacturing and visitor expenditures, GA accounted for a significant contribution of $76.5 billion."

Lately, there has been much discussion on how to encourage operators to acquire equipment that enables precision approaches. However, less attention has been paid to the characteristics of access to GA airports with precision approach. This is of importance to the aviation community since GA airports with precision approach amounted to 159 facilities in fiscal year 2012 (October 2011 to September 2012), up 15% from the previous fiscal year.[3] Some of these airports provide service to remote local communities that would not otherwise be connected to larger metropolitan areas.

This article will refer to six cases (three airports with LPV and three with LP approach capabilities only) in order to evaluate the features of the aircraft operators and any difference of access among the sampled airports. Access to airports may be considered

☆ *Note*: This paper does not reflect the official opinion of the Federal Aviation Administration.

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[1] The information is available at the following FAA site: http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/approaches/.

[2] Part 135 covers operations by any aircraft with a payload of less than 6000 lbs. and a seating capacity of less than 20 seats.

[3] Information retrieved from the FAA's NextGen Performance Snapshots website at http://www.faa.gov/nextgen/snapshots/nas/.

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as a public good (it is not rivalrous and non-excludable). However, while access to GA airports with precision approach may be non-rivalrous, it may be excluded from aircraft that do not have equipment to utilize satellite navigation in the absence of ILS. This may have some implications on aircraft operators' decision to purchase satellite navigation systems, the utilization of the GA airports with precision approach and, as a whole, the best possible provision of such airports in the National Airspace System (NAS).

To understand how access to GA airports with precision approach may be excludable, it is important to specify the type of equipment required for satellite navigation and the benefits it provides to aircraft operators as opposed to ILS.

2. The features and benefits of LPV and LP approaches

The FAA Advisor Circular (AC) 90–107 provides directives to pilots on the type of equipment and procedure required to fly LPV/LP precision approaches. LPV/LP is designed to improve access to GA airports in reduced visibility with approach aligned to the runway (the operational equivalent to Category 1 for Instrument Landing Systems).[4] LPV is an area navigation (RNAV) procedure[5] requiring Wide Area Augmentation System (WAAS). WAAS enhances the strength of the Global Positioning System (GPS) signals in order to improve their accuracy and integrity for LPV/LP precision approaches. LP is designed to use the high precision of LPV for lateral guidance and barometric altimeter for vertical positioning. WAAS navigation relies on three main components: (1) wide-area reference stations and wide-area master stations on the ground, (2) geosynchronous communication satellites in space, and (3) aircraft's GPS and WAAS receivers. LPV/LP operations provide pilots with several benefits:

- It minimizes their need to use step-down (referred to as "dive and drive") approaches, hence improving safety and passenger comfort.
- The glide path does not rely on ground and barometric equipment. With WAAS LPV, pilots do not have to deal with incorrect altimeter settings and lack of local altimeter source.
- It provides the lowest minima with GPS equipment with a decision height of 200–250 feet above touchdown and minimum visibility of half a mile.
- GPS is the primary means of navigation which minimizes pilots' reliance on transponder-based distance measuring equipment (DME) and Very High Frequency (VHF) omnidirectional radio range navigation system (VOR).
- Pilots do not have to continuously check the reliability of their GPS system along the flight and terminal area (GPS integrity monitoring to meet navigation requirements).
- Pilots have more flexibility to fly more direct routes and utilize GPS approaches to selected or alternate airports in case of bad weather conditions with ILS Category 1 precision.
- Pilots can land at small airports at night when they have no altimeter setting.

For an aircraft to fly LPV/LP procedures, it must be equipped with a dual WAAS-capable GPS that must be certified under TSO 145 and 146 as standalone receivers. A specific antenna is also required and existing equipment such autopilot has to be upgraded. From an infrastructure standpoint, the airport or the Federal Aviation Administration (FAA) does not need to install expensive equipment. The implementation of the LPV/LP approaches requires the FAA to design and implement procedures. According to AOPA, the cost of publishing a runway's WAAS procedure was about $50,000 in 2006.[6]

An ILS system requires markings, runway lights, and terrain clearance on the glide path. While providing the advantages of ILS Category 1, WAAS does not require expensive ground infrastructures. A WAAS approach system costs about $80,000 whereas the cost of an ILS can exceed $1.5 million per runway end (at the time of this writing). It is also important to stress that an ILS only covers the runway end where radio transmitters have been installed. AOPA also maintains that "while the annual ILS maintenance cost can be as high as $85,000, the cost to maintain a WAAS approach is less than $3000 every two years."[7] Local communities may find it hard to get federal government's Airport Improvement Program funds if they cannot justify traffic volume. Finally, the efficiency of an ILS system depends on terrain, obstructions and frequency pollution that affect the ILS signal.

In the next section, we will focus on the attributes of access to GA airports with precision approach in light of the theory of public and club goods.

3. Access to GA airports with LPV and LP access and no ILS as a club good

While Samuelson (1954) was instrumental in developing the theory of public goods, both Buchanan (1965) with club goods and Hardin (1968) with common resources goods felt that there was a spectrum of goods between purely private and purely public goods. Over the last fifty years, much has been written on the subject of club goods and interested readers are referred to Berglas (1976), Cornes and Sandler (1986), Sandler and Tschirhart (1997) and McNutt (1999, 2002) for a review of the theory of club goods. In principle, when a public good such as access to GA airports is excludable, it then becomes a club good. Although GA operators may have a different mission (i.e., commercial versus leisure flight), they will share the same utility for access to GA airports with precision approach.

3.1. A utility model for access to GA airports with LPV/LP approaches and no ILS

As mentioned earlier, not all the aircraft have the capabilities of utilizing WAAS to fly precision approaches to GA airports without ILS. Although no specific pilot certification is required to fly an LPV/LP approach, aircraft must have certified equipment that meets the requirements of TSO 145 and 146 as well as upgraded avionics to carry out the procedure. In specify the pilots' utility for access to GA airports with precision approach, we assume that there is no difference among the aircraft operators, whether the flights are commercial or not.

Given E_i as the required WAAS-compliant equipment (a private good) necessary for an aircraft to fly LPV/LP procedures, L as access to a GA airport with LPV/LP procedures and no ILS (club good) and Ops, the number of operations (takeoffs and landings), the utility function for i users can be characterized as follows:

$$U_i = U_i(E_i, L, \mathrm{Ops}) \quad (1)$$

[4] See Appendix A of the FAA's 2012 NextGen Implementation Plan available at http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf.

[5] Area Navigation (RNAV) is one element of Performance-Based Navigation (PBN) with Required Navigation Performance (RNP). The key difference between the two types of PBN is the requirement of on-board performance monitoring and alerting for RNP.

[6] Aircraft Owners and Pilots Association, AOPA welcomes improved WAAS minimums. March 7, 2006. http://www.aopa.org/whatsnew/newsitems/2006/060307waas.html.

[7] Aircraft Owners and Pilots Association, Air Traffic Services Brief: Wide Area Augmentation System (WAAS) retrieved at http://www.aopa.org/whatsnew/air_traffic/waas.html.

Table 1
Private operators (N-registered aircraft) and equipment capabilities at selected airports (June–August 2012).

Facility	Counts of N-registered aircraft	N-registered aircraft out of total aircraft (%)	IFR for N-registered aircraft (%)	Surveillance equipment for N-registered aircraft		Nav/Com (*W* and *G*) for N-registered aircraft (%)	Requested PBN-use for N-registered aircraft (%)	Equipment size for N-registered aircraft (wake vortex incidence) (%)		
				S (%)	*C* (%)			*L*	*M*	Total
BCT	770	77	73	49	30	39	30	55	45	100
BMG	526	85	82	28	64	29	22	80	20	100
ELM	529	42	82	53	35	34	51	46	54	100
FAT	282	28	33	11	88	12	10	87	13	100
LYH	587	64	66	14	66	15	14	88	12	100
MTN	937	88	36	14	24	16	13	86	14	100

Source: NASQuest.
C, Transponder Mode *A* and Mode *C*; *S*, Transponder Mode *S* including both pressure altitude and aircraft identification transmission; *W*, reduced vertical separation minimum; *G*, Global Navigation Satellite System (GNSS); *L*, Light aircraft (maximum take-off weight of 15,000 lb or less); *M*, medium (maximum take-off weight between 15,001 and 300,000 lb).

with

$$\frac{\partial U_i}{\partial \mathrm{Ops}} > 0 \quad \text{if Ops} < K \tag{2}$$

K represents the airport's available capacity, that is, the expected number of operations that can safely be accommodated in and out of a given airport, by unit of time (usually an hour), given the following conditions: (1) traffic mix, (2) wake vortex separation requirements, (3) runway configurations, (4) wind direction and speed, and (5) minimum ceiling and visibility conditions that determine meteorological approach conditions (visual versus instrument).

Equation (1) is subject to

$$I = E_i + \frac{C(L, \mathrm{Ops})}{\mathrm{Ops}} \tag{3}$$

The marginal cost of provision is

$$\frac{\partial C}{\partial L} > 0 \quad \text{and} \quad \frac{\partial C}{\partial \mathrm{Ops}} > 0 \tag{4}$$

Using the Lagrange multiplier,

$$L = U_i(E_i, L, \mathrm{Ops}) + \lambda\left[X, -E_i + \frac{C(L, \mathrm{Ops})}{\mathrm{Ops}}\right] \tag{5}$$

We obtain the marginal rate of substitution

$$\mathrm{MRS}_{\mathrm{EL}} = \frac{\partial U_i/\partial L}{\partial U_i/\partial E_i} = \frac{\partial U_i}{\partial L} \times \frac{1}{\mathrm{Ops}} \tag{6}$$

And the marginal rate of substitution

$$\mathrm{MRS}_{\mathrm{EOps}} = \frac{\partial U_i/\partial \mathrm{Ops}}{\partial U_i/\partial E_i} = \mathrm{Ops}\left(\frac{\partial C}{\partial \mathrm{Ops}}\right) - \frac{C(L, \mathrm{Ops})}{\mathrm{Ops}^2} \tag{7}$$

(8) $\mathrm{MRS}_{\mathrm{EOps}} = \frac{1}{\mathrm{Ops}} \times \frac{\partial C}{\partial \mathrm{Ops}} - \frac{C(L, \mathrm{Ops})}{\mathrm{Ops}^2}$

3.2. The sample of airports

The sample includes six airports. Three of them feature RNAV LPV capabilities: Boca Raton, Florida (BCT); Bloomington, Indiana (BMG); and Lynchburg, Virginia (LYH). The other three offer RNAV LP capabilities: Elmira/Corning, New York (ELM); Fresno/Yosemite, California (FAT); and Martin State Airport, Maryland (MTN). These airports were selected on (1) the basis of geographical locations, (2) approach capabilities (LPV versus LP), and (3) the availability traffic data. The data originated from filed flight plans recorded in FAA's NASquest[8] for the months of June to August 2012 when traffic is at its peak.

[8] The database is accessible at https://nasquest.faa.gov/v20/login.cfm.

Table 1 provides the number of privately-owned GA aircraft (N-registered), their capabilities based on transponder type,[9] onboard navigation/communication equipment and aircraft size measured by wake vortex incidence. The heavier the aircraft, the more separation is required to mitigate wake turbulence for the trailing aircraft. The type of onboard surveillance/communication equipment may be an indicator of aircraft operators' preferences for precision approaches at GA airports without ILS that can be measured by the cost of equipage.

The percentage of IFR flights is the highest at locations where planes are equipped with Mode S surveillance equipment and *W*/*G* navigation/communication equipment. At those airports, aircraft operators are more likely to request performance-based navigation procedures mainly in midsized aircraft. ELM and BCT experienced the highest number of requested PBN procedures among the six airports. BCT is subject to noise abatement procedures in effect at all times for all aircraft types, while the use of precision approach in poor weather conditions improve access to ELM surrounded by mountains.

Table 2 provides the same information for aircraft identified by a flight number. This group of operators includes commercial air carriers (air carriers and air taxis that include commuter airlines) as well as fractional flights.

Commercial air carriers are more likely to fly instrument flight rules. Most jets operate in Class A airspace (between 18,000 and 60,000 ft) for the cruise portion of their flight. In the case of BCT and BMG, there is a higher proportion of aircraft equipped with Mode S transponders and *W*/*G* navigation/communication equipment that request the use of PBN. BCT features a higher percentage of heavy aircraft (mainly fractional jets) compared with the other airports. Airspace use restrictions due to noise abatement procedures likely favored the need for precision approaches into BCT.

The assumption of no difference between the two groups can be determined using the Brown-Forsythe test based on variance homogeneity. At a 95% confidence level, we accept the null hypothesis that there is not a significant difference among the six airports in the variances of the type of communication and surveillance equipment as well as in the percentage of requests for PBN procedure whether the aircraft is N-registered or flight-identified. The significance value is 0.6496 ($p > 0.05$). This may have some important policy implications: Heterogeneous aircraft operators may form a homogeneous population through their shared utility for access to the GA airports with precision approach.

[9] The mode C transponder provides pressure altitude and is combined with the 3/A type (4-digit octal code). The mode S transponder features a 24-bit address format and is capable of multiple information format. The mode S transponder minimizes over-interrogation of the transponder, especially in busy areas as well as automatic collision avoidance.

Table 2
Commercial air carriers and private operators identified by flight number (June–August 2012).

Facility	Counts of aircraft *w*/flight number	Aircraft with flight number out of total aircraft (%)	IFR for aircraft *w*/flight number (%)	Surveillance equipment for aircraft with flight number		Nav/Com (*W* and *G*) for aircraft *w*/flight number (%)	Requested PBN-use for aircraft *w*/flight number (%)	Equipment size for aircraft with flight number (wake vortex incidence)			
				S (%)	*C* (%)			*H* (%)	*L* (%)	*M* (%)	Total (%)
BCT	283	23	96	82	9	84	75	11	16	73	100
BMG	89	15	98	69	30	63	49	0	49	51	100
ELM	736	58	99	30	62	48	4	0	25	75	100
FAT	718	72	96	67	32	41	5	1	9	90	100
LYH	919	36	66	14	66	15	14	0	88	12	100
MTN	128	12	87	27	65	33	29	1	43	56	100

Source: NASQuest.

This can be achieved if regulators require standardized equipment and air traffic service providers take into account aircraft capabilities in service.In the next section, we will focus on the factors that support the provision of access to the GA airports with precision approach.

4. The provision of access to GA airports with LPV and LP and no ILS

Government regulators can encourage aircraft owners' to invest in WAAS-compliant equipment through changes in the procedures and level of service. In this article, the level of service refers to the handling of arrival and departure flows by the air traffic service providers based on aircraft capabilities and pilots' request for precision approach. For instance, the aircraft best capable of utilizing satellite navigation would have priority over others in an arrival stream. Presently, the first come is usually the first served aircraft.

One issue associated with a change in the level of service to reflect aircraft capabilities is equity of access. While an emphasis on aircraft capabilities may make some operators better off, it is also likely to make others worse off who will be excluded from the airport. Since access to GA airports with precision approach is non-rivalrous, the fact that some aircraft cannot use precision approach in Category 1 situations may reduce the overall efficiency of satellite navigation. The trade-off for a change in the level of service is improved access for equipped aircraft in bad weather conditions as well as greater pilots' flexibility to land regardless of ILS availability. Determining a level of service based on aircraft capabilities would set clear expectations of service limitations and reduce aircraft operators' incentives not to invest in precision approach equipment. Changing the level of service and establishing equipment standards address the problem of 'forced riders' (Loehr and Sandler, 1978, p. 27).

Second, the establishment of a level of service based on aircraft capabilities is likely to minimize operators' uncertainty as whether they can utilize their investment in equipage. The ability for pilots to utilize precision approach depends on the disposition of air traffic control to authorize such a procedure and for pilots to carry them out. Investing in satellite navigation equipment may represent a risk if aircraft capabilities to fly precision approaches may not be granted at all times.

5. Final remarks

The cases suggested that aircraft operators were homogeneous and therefore shared the same utility for access to airports with precision approach. The type of aircraft operator or flight mission may not be a predictor of what surveillance and communication equipment is likely to be onboard the aircraft. While access to GA airports is a public good, circumstances such as poor weather conditions will exclude some operators from getting access when they cannot use ILS. Air traffic service providers may support flight efficiency at the airspace and local level by changing the level of service in such a way that it encourages aircraft capabilities and pilots' flexibility to fly precision approach when there is no ILS.

Club goods are usually characterized as organizations whose consumption of a good is restricted to a group of users. As McNutt (1999) put it, "the economic theory of clubs represents an attempt to explain the under-supply equilibrium of a public good provision." This appears to be the case of access to GA airports with precision approach. The volume of traffic at these sampled airports makes congestion very unlikely even though commercial air carriers and general aviation users may be mixed.

Federal regulators can mandate that WAAS-compatible equipment be installed onboard aircraft based on established standards agreed upon by the industry. However, private owners who fly occasionally may have neither the incentive, nor the financial resources to purchase expensive equipment. Technologies evolve rapidly and standards are likely to change, thus making equipment obsolete and investments riskier. Access to GA airports with precision approach may be subsidized. However, regulators will have to determine how to generate resources (for instance, through a fuel tax or increased landing fees). Restricting access through taxation and regulation may raise further questions of equity and 'forced riders'.

It appears that the determination of a level of service may represent a mechanism to justify the expansion of access to GA airports without ILS. Users should be able to mix but with the expectation that their aircraft capabilities will give them priority in service in instrument meteorological approach conditions. The determination of a level of service based on aircraft capabilities would present several advantages. It would allow aircraft operators to reveal their preferences for access to the GA airports without ILS. Second, it would contribute to a reduction in the 'administrative' costs related to the air traffic management's handling of aircraft with different capabilities (mainly controllers' training in queue management). Third, a level of service that stresses aircraft capabilities is more likely to transform a heterogeneous into a homogeneous group of aircraft operators who are not only interested in maximizing their own utility but those of others who share an equal interest in access. If the level of service does not take into account aircraft capabilities, rational aircraft operators would not have an incentive to equip because they would get access anyway.

Further research may be necessary to determine whether changing the level of service may have an impact on the degree of access to GA airports as technologies become more accessible to all operators. Access to the GA airports with precision approach raises the important issues of incentives for satellite navigation equipage, the role of regulators for supporting demand for access to secondary airports and the expectation of a certain level of service to encourage aircraft operator to equip for precision approach.

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