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To: Forecast Team
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Subject: **Impact of Climate Change and Sustainability on Future Aviation Demand**

The question of how public policy and societal concerns about climate change and sustainability should be reflected in the aviation demand forecasts was raised at the second PAG Forecast Subcommittee meeting on December 12. This memo documents some initial thoughts on how we might respond to that question:

These two issues are clearly of increasing societal and political concern and have already led to legislation and public policy actions in a number of states, including Oregon. On December 5, 2007 the State of California together with a number of other states and interested parties petitioned the U.S. Environmental Protection Agency (EPA) to regulate greenhouse gas emissions from aircraft. While it remains to be seen how the EPA will respond or what subsequent actions may be taken, it is clear that concerns about the impact of aviation on climate change are likely to increase in the future. In addition to concerns over greenhouse gas emissions, sustainability concerns are also likely to focus on continued consumption of oil-based fuel by aviation. The question from the perspective of future aviation demand is what impact these concerns, legislation, and policies will have on future levels of air traffic. Obviously this will depend in large measure on the actions that are taken, either by individuals, organizations, or governments.

These actions could take at least seven forms:

1. Individuals or organizations could choose to reduce the number of air trips that they make;
2. Individuals or organizations could voluntarily choose to pay a carbon offset fee to mitigate the emissions created by their air trips;
3. Governments could impose a mandatory carbon offset tax or other emission-related tax or fee on air travel;
4. Governments could set greenhouse gas emission targets and establish an emissions trading scheme to encourage airlines to exceed their targets and require those airlines that fail to meet the targets to purchase emissions credits to make up the shortfall;
5. Governments could set progressively more restrictive standards for aircraft engine emissions and require the phase-out of those aircraft (or at least those engines) that fail to meet the standards;
6. Governments could set limits on the number of flights;

7. Governments or private sector organizations could support or undertake expanded research into alternate fuels and advanced aircraft technology that reduces emissions or fuel consumption (the two issues are closely related, since reducing fuel consumptions reduces carbon emissions).

The potential impact of each of these different actions on the future demand for air transportation is discussed in more detail below, together with suggestions for how these actions could be reflected in the aviation demand forecasting process.

Reduction in Air Travel Propensity

If significant numbers of individuals or organizations decide that as a society we are making too many air trips and choose to forego air trips that they would otherwise make, this will translate into a reduction in the level of air travel propensity (the number of annual air trips per person), other things being equal. Actually, what really matters is not the number of air **trips** *per se* but the amount of air travel in passenger-miles. It has a much greater effect to forego an air trip from Portland to London than one between Portland and San Francisco. Although the greenhouse gas emissions per mile vary with the length of the trip, this is a second-order effect compared to the total length of the trip.

From the perspective of air travel demand modeling, this would translate to a shift in the model coefficients that relate air travel demand to the socioeconomic and air service causal factors. In other words, the model coefficients used for forecasting should be different from those estimated on historical data. Of course, other things could result in a change in the relationship between air travel and the socioeconomic and air service causal factors, including changing needs for business travel and changes in other costs that impact disposable income. For example, an increase in the price of oil not only increases airfares by increasing the cost of aviation fuel but also affects household and business expenditures on surface transportation and utilities, reducing the amount of money available for activities involving air travel, for any given level of household income or business revenue. Thus the issue of how model coefficients should change over time ought to be addressed irrespective of the extent to which it is believed that individuals will choose to forego air trips.

There is very little basis at present for knowing to what extent individuals might reduce their air travel out of a concern for climate change. The recent survey of Portland region households undertaken by Riley Research Associates for the PDX Airport Futures Study asked how willing respondents would be to decrease their travel to reduce the overall demand for travel and environmental impact. Of those providing an indication of their willingness to decrease their travel, about 23% stated that they would be "very willing" to do so, while about 36% stated that they would not be at all willing to do so. Of course, it is one thing to give this answer in a survey and another thing to actually do it. Also, the percentage of respondents who indicated that they would be willing to reduce their travel declined with increasing income. Thus those who make the most air trips were least willing to reduce their travel. It should also be noted that the question asked about willingness to reduce travel, and did not specifically mention air travel. While the respondents may have understood the question to refer to air travel, given the earlier questions in the survey, it is entirely possible that some respondents interpreted the question more generally. Furthermore, the wording of the question provides no indication how much reduction those who expressed a willingness to reduce their travel had in mind.

It can also be argued that widespread public awareness of the threat posed by climate change is a relatively recent phenomenon, and there are many who are not yet convinced of the need to modify their lifestyle to address this. As the consequences of global warming become more apparent and the need to take actions to reduce or offset greenhouse gas emissions becomes more widely accepted, willingness to consider lifestyle changes may well increase.

Therefore any assumptions about the extent that individuals might be willing to reduce the amount of air travel they undertake will be highly speculative. Even so, this can be addressed in probabilistic forecasting through assumptions about the likely future change in air travel propensity. Operationally this can be represented by a reduction in one or more coefficients of the air travel demand model used to generate the forecast. The specific coefficients to be adjusted and the amount of the adjustment will depend on the details of the model and how it is assumed that the reduction in air travel will vary with income (or other factors).

It should also be noted that the willingness of individuals to reduce air travel may well depend on what other actions are taken to address the impact of aviation on climate change. If individuals perceive that the greenhouse gas emissions of aircraft are being addressed through such measures as a carbon tax or trading of emissions credits, it can be expected that they will feel less need to forego the benefits of air travel. Therefore the assumptions used in any given forecast should be viewed as a package that considers the full range of strategies that could be pursued and not treated individually.

Voluntary Carbon Offset Fees

A number of companies (both non-profit and for-profit) currently exist that maintain websites where air travelers can calculate the carbon emissions (as tons of CO_2) for a given air trip and pay a voluntary carbon offset fee. These funds are then invested in projects to reduce or mitigate greenhouse gas (GHG) emissions. Such payments could be encouraged by firms or other organizations through travel reimbursement policies or making offset payments directly. For those individuals who voluntarily choose to pay a carbon offset fee in addition to the airfare, this can be viewed as an effective increase in the airfare. There are two assumptions that need to be made to incorporate this approach into a forecast model: the percentage of air travelers who elect to pay a voluntary carbon offset fee and the amount of the fee. Unfortunately, the air travel emissions calculators used by different companies give different estimates of the carbon emissions for a given trip and the offset fee rate per ton of CO_2 varies by company. A comparison of nine different companies by the Tufts Climate Initiative (www.tufts.edu/tie/tci/carbonoffsets/index.htm) found that for a round trip by air from Boston to Washington, D.C., the offset cost varied from $1.31 to $12.25. However, it is likely that as those choosing to make voluntary carbon offsets become more informed and the practice becomes more widespread, this range may close. After all, for those who choose to do it at all, there is no reason to underestimate the cost to offset the emissions.

Mandatory Taxes or Other Fees

The United States government could decide to impose a mandatory tax or fee on air travel and use the revenue to support initiatives to reduce carbon emissions in other sectors (for example power generation or support for mass transit). The most logical tax or fee would be a fixed amount per gallon of fuel, since this provides the most direct linkage to the carbon emissions and has the added advantage that it would provide an incentive to airlines to use more fuel-efficient aircraft. It can be assumed that the airlines would pass this tax on to air travelers through the airfares, and thus could be modeled through assumptions about future airfares. The two key questions from the perspective of forecasting the effect on aviation demand of such a tax is when it would be implemented and how stringent it would be. It is possible that such a tax may be introduced progressively to give airlines time to adjust and minimize any disruption to the industry. Both aspects can be reflected in a probability distribution for any given year that expresses the likelihood that the tax would be less than any given amount in that year. An example of such a probability distribution is shown in Figure 1.

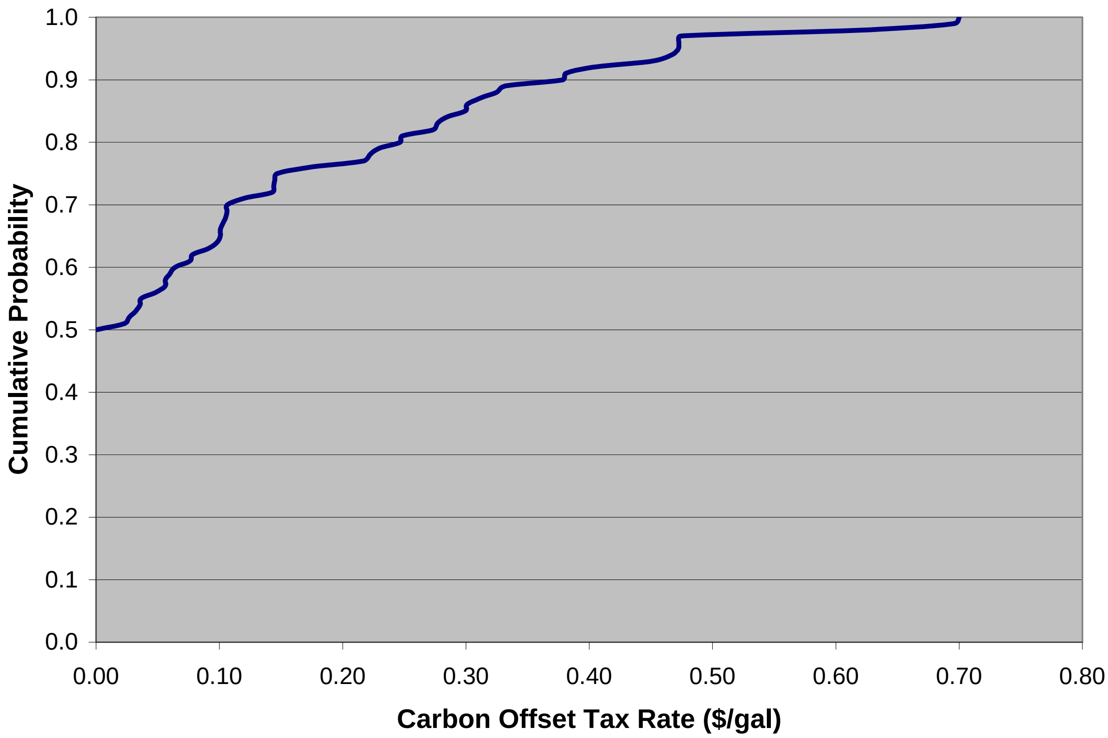

Figure 1 Hypothetical Cumulative Probability of a Carbon Offset Tax for 2012

The cumulative probability shown in Figure 1 was generated using a three-parameter model that varied the initial year the tax would be in effect, the number of years over which it would be phased in, and the final tax rate, which varied from $0.20 per gallon to $0.70 per gallon. The initial year the tax would be in effect varied from 2010 to 2015 and the length of the phase-in period was varied between zero, five and ten years. Distributions were assumed for each parameter and a Monte Carlo simulation was performed for 100 trials to generate the probability distribution (the curve would be smoother with more trials).

It can be seen that in 50 percent of the cases, the tax rate projected for 2012 was zero because the tax would come into effect in a later year. Of those cases where the tax was projected to be in effect by 2012, more than half had a projected tax rate below the assumed lower limit of the final tax rate due to the reduction in the tax rate during the phase-in period. This example illustrates how a single distribution can be generated to combine the effects of several different factors, in this case different potential tax rates, differing initial years for the tax to become effective, and differing phase-in periods, which interact to affect the likely tax rate in any specific year.

Even if the U.S. Federal Government does not take any significant action to limit aircraft greenhouse gas emissions, states or even airports could do so. The legal authority of states to impose taxes or fees on aviation to fund efforts to reduce greenhouse gas emissions is likely to be subject to challenge in the courts, but some states already tax aviation fuel for other purposes so it would be difficult to argue that they do not have the legal authority to increase these tax rates. Similarly, airports could impose a flowage fee on fuel sold at the airport to purchase carbon offset credits. This might result in airlines tankering fuel from airports that do not charge the fee, which could increase emissions due to the additional weight of the tankered fuel. However, the ability of airlines to do this would become increasingly constrained if other states and airports adopt similar measures.

Emissions Targets and Emissions Trading

The European Union is moving toward establishing an emissions trading scheme for air transportation in Europe. Emissions targets would be established and airlines would be required to reduce their emissions to meet the targets (for example by using more fuel-efficient aircraft) or purchase emissions credits for the balance. Depending on the targets that are established, such a scheme would increase airline costs, which would be passed on to air travelers through higher fares. The costs would depend on both the stringency of the targets (for example, whether they merely aim to merely prevent total emissions from increasing or attempt to reduce total emissions and how quickly) as well as the future cost of emission credits. Estimation of the cost implications of such a scheme, while fairly complex to perform, is fundamentally no different from estimating the cost impact of a carbon offset tax.

Regulating Aircraft Engine Emissions

Establishing more stringent standards for aircraft engine emissions and requiring the phase-out of engines not meeting those standards would also tend to increase airline costs and hence increase airfares. The extent of the cost impact would obviously depend on the standards that are set and how much time airlines are allowed to bring existing aircraft into compliance. Aircraft manufactured today are already significantly more fuel-efficient (and hence produce less greenhouse gasses) than older aircraft. Aircraft and aircraft engine manufacturers are already anxious to improve fuel efficiency as much as possible for other reasons, so it is likely that the industry will pursue technological opportunities to improve fuel efficiency of new aircraft with or without more stringent government emission standards. The real question is what to do about the existing fleet.

Calculation of the cost impact of any particular phase-out schedule involves determining which aircraft types will be affected at each point in time and the anticipated capital cost of replacing the engines (or the aircraft), less the benefit of the fuel and other savings that will result from that point on. Older aircraft and engines are generally more expensive to maintain than newer ones, so in addition to the fuel savings there are likely to be significant maintenance savings from replacing older equipment.

Limitations on the Number of Flights

This is perhaps the most draconian approach to reducing aircraft emissions and would be politically extremely difficult to implement. Obviously, aircraft emissions depend not only on the number of flights but their duration and the size of the aircraft, so to be effective such an approach would have to consider stage length and aircraft type as well as the number of departures. The impact of such an approach on any given airport would also depend on whether the limitations are imposed at the level of the airline, the airport, or the city-pair market. Given the inherent difficulties in determining how to allocate a reduction in flights across different airlines, airports and markets, the most likely approach (assuming a decision is made to impose limitations in the first place) would be some sort of auction of available capacity, in much the same way as the Federal Communications Commission allocates the radio frequency spectrum. The outcome of the current debate over how to manage the limited capacity at New York LaGuardia Airport may provide an indication of how a more extensive approach to limiting flights might be structured.

This is perhaps the most difficult of the policy options to incorporate into an aviation demand forecast, since the way in which it might be implemented will have a profound effect on the available capacity not only at a given airport but in every market at that airport. However, such an approach is likely to be so highly contentious that it would be very difficult to assess the relative likelihood of alternative implementation approaches being chosen or even define what approaches might be considered. Rather than attempt to analyze the implementation process, it may be adequate for the development of forecasts for a given airport to simply consider different outcomes in terms of the seat capacity in each market served from the airport. The first step would be to establish the overall limitation on seat capacity for the airport as a whole, and then a second step would determine how that capacity would be allocated among the different markets. The first step can be determined from an assessment of the probability of establishing different capacity limits. The second step could consider two different allocation outcomes among the different markets. The first outcome would preserve the existing distribution of capacity among the different markets. The second outcome would distribute the capacity among the different markets in a way that maximizes airline profitability. In reality, assuming such a situation were to occur, the actual distribution of capacity would most likely lie somewhere between these two outcomes. Some adjustment would occur compared to the current distribution, but it would be unlikely that the airlines could achieve the full profit maximizing allocation of the available capacity.

Although a limitation on seat capacity necessarily imposes a limitation on passenger traffic, the relevant information from a planning standpoint is what effect this has on airfares in each market and the types of aircraft being operated. These are determined directly by the profitability analysis in the case of the second allocation outcome and can be determined by a similar analysis in the case of an allocation outcome that preserves the existing distribution of capacity among the different markets. In fact, if the profitability optimization begins with the current distribution of capacity, the first step in the optimization will generate the capacity constrained airfares in each market for the current distribution of capacity.

Although such an approach is conceptually fairly straightforward, implementation of the profitability optimization to determine the capacity distribution in the second step is likely to be computationally challenging, and may well be beyond what can be accomplished within the available resources and time for the current forecast. A simpler approach would be to incrementally adjust fare assumptions until the resulting traffic level is consistent with the assumed limitation on the number of seats, using appropriate assumptions for load factor.

Development of Alternative Fuels and Advanced Aircraft Technology

The aircraft manufacturers and government research agencies such as NASA have been pursuing advanced aircraft technology for many years with the goal of improving fuel efficiency, which also reduces GHG emissions. More recently, there has been an upsurge in research interest in alternative fuels, such as the Commercial Aviation Alternative Fuels Initiative (CAAFI), a joint industry/government program to develop and implement synthetic and other alternatives to oil-based jet fuel. Although primarily responding to the current price of oil, alternative fuels may also reduce GHG emissions. Development of alternatives to oil will of course address sustainability goals, particularly alternatives that use renewable feedstock.

Government support of research into alternative fuels and advanced aircraft technology to reduce greenhouse gas emissions will not directly impact the cost of air transportation unless the research is funded through a tax on aviation. In the short run, any such tax will of course increase the cost of air travel or air cargo shipments proportionately, depending on the tax structure. In the long run, it can be expected that such research will not only reduce emissions and fuel use, but also lead to reduced airfares or air cargo rates due to the reduction in fuel costs. The net impact on other airline costs is less clear. The research may well generate results that facilitate savings in other costs, such as maintenance. On the other hand, the technologies resulting from the research that enable reduced emissions or fuel savings may require higher levels of maintenance or capital cost to implement. It can be expected that the cost savings from reduced fuel use will more than offset any increases in other costs or the technologies would not be implemented. Therefore on balance air fares and air cargo rates should decrease.

Thus the effect of such programs can be included in aviation demand forecasts through two different sets of assumptions, the first addressing any near-term increase in aviation taxes to pay for the research and the second addressing the longer-term reduction in aircraft operating cost due to improved fuel efficiency, and cheaper alternative fuels.

However, it is quite likely that the improvements in fuel efficiency and lower emissions from alternative fuels that are economically competitive with oil will not be enough to offset the growth in air travel, much less achieve a significant reduction in total GHG emissions, at least in the 20 to 30 year time horizon. Therefore it may become necessary to resort to alternative fuels (principally hydrogen-based) that could be more expensive than oil or cost-competitive alternative fuels but that have significantly lower GHG emissions, resulting in a potential increase in the cost of air travel. Such a scenario would obviously require regulatory intervention to force the use of a more expensive, but environmentally superior, technology. One possible driver for such a situation would be an emissions trading regime where the cost of purchasing emissions credits for oil-based or cost-competitive alternative fuels becomes so great that airlines find it economically attractive to switch to a hydrogen-based fuel.

Because this would require replacing the aircraft fleet as well as changing the fuel technology, it is unlikely that it could be implemented to any significant extent within the next 30 years. Development of hydrogen-fueled aircraft would require at least 10 years, quite likely longer, and then subsequent replacement of the existing aircraft fleet would require several decades. Thus this scenario would only have a significant impact on forecasts beyond the 25 to30-year time frame.