Intercity passenger transportation is a time and energy intensive activity. Despite a growing social consciousness toward “green” alternatives, travelers continue to choose routes and modes based primarily on the travel time and cost. This effect is well-represented in the dominance of air travel for passenger trips even for fairly short trips, for which air may offer the shortest travel time, but also the largest fuel consumption per passenger-mile of travel. While long distance trips of greater than 500 miles are dominated by air travel, short- and medium-haul trips compete with surface modes when comparing total travel time and cost. However, from the perspective of comparing cost of provision and energy consumption on a passenger-mile basis, short-haul air travel is far less efficient than surface modes, especially high-occupancy surface vehicles.

Airlines have dominated long-distance intercity travel since the dawn of the jet age in the late 1950s; carriers offer schedules that compete for market demand according to their own strategy for profit maximization. In seeking ever increasing efficiency and geographic coverage, most air service networks have evolved to hub-and-spoke structures, connecting short-haul regional flights with long distance flights. Attempts by airlines to offer increased service at the most desirable travel times can exceed an airport’s capacity to handle the desired flight schedule. Such competition results in congestion during times of greatest demand, and the ensuing queues impose additional external costs onto the system and region. These costs include the value of wasted time due to travel delays on air travelers, incremental personnel costs, unnecessary fossil fuel consumption and greenhouse gas (GHG) emissions from both air and ground vehicles queueing for airport access. Since less popular destinations give way to more profitable routes for high-value scheduling slots, airlines impose long layover times on passengers transferring to these locations. Schedule-driven congestion delays are magnified when adverse weather restricts airport or airway capacity. According to the USDOT Bureau of Transportation Statistics (BTS), weather accounts for approximately 70 percent of such delays nationwide. For the busiest airports, these delays not only affect travelers locally, but can echo throughout the national airspace system (NAS), magnifying the costs of delays across the country.

Due mostly to the segmentation of US transportation finance and regulatory agencies, solutions to air transport congestion have remained primarily within the domain of the air mode [1][2]. Constraints on airport throughput have resulted in more runways and tighter aircraft spacing rules; airway congestion has resulted in finer partitioning of airspace and air traffic control allocation.

One strategy for increasing the efficient use of airport capacity is through shifting trips to alternative modes, specifically to surface modes such as high-speed rail, conventional rail service, motor-coach/van service, etc.[3][4][5] Mode substitution policies that shift demand for the selected flights at congested airports might provide substantial relief for operators and travelers through strategically targeted schedule shifts. In addition they may lead to important energy and environmental benefits. The targeted flights would be those that have substitutable ground mode alternatives, providing trips to destinations with time and cost characteristics competitive with air travel.

Methodology
The goal of this research is to explore the trade-space of the costs and benefits of shifting short-haul flights to alternative surface modes using a broad spectrum of generalized performance measures. These include traveler and environmental costs such as: total travel time, travel costs, delay costs (associated with runway slot value), energy consumption, noise and GHG emissions levels both on the air and ground transportation networks. This methodology requires looking beyond the traditional boundaries of how long distance travel is currently delivered through the air transport network.
Using a record of actual flown air travel itineraries, detailed air transport schedule data, and a variety of geographic, transportation performance and cost data, alternative surface transportation service was posited between Chicago O’Hare International Airport (ORD) and airport destinations within 200 miles. Figure 1 provides the scheme of the trips segments, terminology and scope addressed in this work. Trips destined for regional cities and communities begin at diverse origins across the country. Since the origin-destination pairs consist of markets too small to be served by direct service, air travel is routed through a transfer point at Chicago O’Hare. This research considers substituting air trip segments to and from these short-haul destinations.

In-bound trips are measured from the gate arrival time of long-haul flights into O’Hare and include transfer times, travel segments and curbside access of either short-haul flights or motorcoach service. Out-bound trips originate curbside at the small regional airports, and include gate access time, travel time, and layover times at ORD ending at boarding the long-haul leg. An important assumption here is that ground service benefits from through baggage, airport security screening practices, and terminal gate boarding in much the same way as the comparable air service.

The aviation data comes primarily from three main sources: daily airline schedule data describing, in detail, all scheduled passenger and cargo flights [6]; a ten-percent sample of purchased itineraries for passengers including flight segment data [7]; and aviation system performance metrics providing traffic counts and operating conditions [8]. The last also provides measures for air traffic delays during taxi and flight portions aggregated for 15 minute time periods. Additional data sets from the American Bus Association survey data contained cost and performance for motorcoach operations [9]; the European Environment Agency [10] and US DOT - Bureau of Transportation Statistics [11] contained fuel consumption and conversion rates for energy comparisons; and cost analysis of the air transport system by GRA, Inc. [12]. While limited in their completeness and accuracy, these datasets are widely used and served to identify rough estimates of system performance. Additional flexibility and parameter calibration was accomplished using parameter indices discussed in further detail in the results section.

Select Results

An example is presented to illustrate the comparison between the air route and the surface alternative routing between Chicago and Milwaukee (MKE). Figure 2 (left side), presents an illustrated view of the air trip route (blue) and the surface highway routing (orange) using satellite imagery from Google Earth as backdrop. The right side of Figure 2 displays the corresponding time-space diagram for these modal alternatives – the air trip indicated in blue and the surface trip in brown.
To identify wide ranges of the trade space, Monte Carlo simulation techniques were used to sample market parameters based on empirical data to estimate resource impacts over a range of conditions. By adjusting the distribution and indices of various travel parameters, the simulation results were used to identify mode dominant regions of the trade-space for individual short-haul destinations. Parameters such as airport layover times, flight block times, airport ingress and egress and average highway speeds were simulated according to measured data and the total travel times for both modes were plotted. The data scatter (as shown in Figure 3) was plotted on a surface – air travel time diagram to determine the range of outcomes experienced by a consumer. Comparing the results shown in Figure 2 of a sample Milwaukee trip with the light blue scatter at the left side of Figure 3 (labeled MKE) indicates that while a surface trip is more advantageous in total travel time, not all travelers experience this advantage. The color scheme in the background of Figure 3 illustrates the trade-space regions where modal dominance may exist – the lower right region intensity (blue color) indicates air travel dominance where the brown intensity in the upper left indicates surface dominant destinations.

Also shown in Figure 3 are two other short-haul airport destinations, Indianapolis, IN (IND) and Springfield, IL (SPI). These were selected to illustrate the trade-space regions where modal dominance may exist. Trip samples to Milwaukee, WI (MKE), shown in light blue, indicate that the ground service tends to dominate over air service. The opposite is true for Indianapolis, shown in dark blue. This research also illustrates that this is not purely a function of travel distance when comparing Indianapolis with Springfield, shown in lavender, which are roughly equidistant and equally accessible from ORD. Springfield has many instances where surface transportation is more competitive than air even at that distance.

To provide a richer understanding of the trade-offs between surface and air modes, similar comparisons are computed for all destinations considered in this study in terms of energy consumption and operator costs. Energy computations determine primarily line-haul energy consumption by vehicle type. Air transportation energy consumption accounts for fuel burned with currently scheduled aircraft types, consumption efficiency, and the level of congestion encountered within specific markets. Motorcoach energy consumption accounts for mileage, frequency of service, and fuel efficiency.
Operator cost results account for the direct costs of operating vehicles including fuel and maintenance, labor, and amortized vehicle ownership costs based on estimates from 2000-2002. The cost values refer only to the service being provided and do not include opportunity cost impacts of air service removal, nor does it include the start-up costs of bus service.

The results illustrate the trade-off in travel time, service frequency, energy and operator costs of surface trip alternatives. Input assumptions are linked together in a spreadsheet model to flexibly explore the trade-offs of modifying operating assumptions across the measurement domain through the use of user-adjustable input variables. One particular setting, assuming three motorcoach departures for every one short-haul air departure for all destinations, is shown in Figure 4. As with the color scheme orientation in Figure 3, the upper left brown shading indicates surface alternative service dominance versus the lower-right region’s blue intensity indicating air travel dominance to selected destinations. Figure 4 also contains computations for the range of airports considered in this study (color-coding key shown at far right).

**Conclusion and Extensions**

For flights connecting through Chicago O’Hare destined for airports within the study region considered, (within 200 miles of Chicago), providing alternative motorcoach service in lieu of originally scheduled short-haul air travel has the very real potential to provide competitive travel service. From the perspective of the total travel time of passengers, mode substitutability is not solely attributed to travel time or distance. Many additional market factors create the possibility for competitive ground service with moderate travel time effects (shown in Figure 3 and Figure 4 – left). Additionally, when comparing on a per passenger-mile basis, ground mode substitution provides a significant energy saving alternative for reducing transportation environmental effects (Figure 4, middle) and a highly cost-effective option for all destinations (Figure 4 - right).

There are several key aspects that this research will address next including an analysis of the marginal effects of input parameters and assumptions, an exploration of the externalities created by the proposed modal shift and the comparison of surface and air transport modes with respect to traveler utility. Quantifying the effects of the input parameters and assumptions on the value of the air-to-surface comparison within the trade-space serves to identify the most important (and least important) factors to providing alternative transportation service within these markets. By shifting the destination (or origin) of the short-haul trip away from the airport location, it may be possible to adapt bus routes to decrease the overall trip costs by delivering travelers closer to their final destinations. Exploring the trade-off for this flexibility will address additional traveler costs and savings, infrastructure implications and commonality assumptions to compare with the air transport mode.

**Select References**