The Economic Benefit of Data-Communication Technology on the New York Metroplex Area

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PRELIMINARY

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Abstract

The aim of this paper is to estimate the economic benefit for the New York Metroplex area of the controller-to-pilot communication standard known as Data-Communication. RAMS simulation software was first used to evaluate the potential impact of the new technology on airport operations in the three airports of LaGuardia, Newark and John F. Kennedy. The new technology would allow for a greater number of operations and reduce the average hourly workload for air traffic controllers. We employ a two steps procedure. First, we estimate a benefit function per number of hourly operations. Second, using the empirical distribution of hourly operations and the benefit function found in step one, we compute the average daily benefit from the technology as the reduced cost from delays plus the net effect on controllers workload due to its implementation. The procedure is applied at each airport individually and to the metroplex area as a whole. Our estimates show that the introduction of Data-Comm would yield significant savings in the New York Metroplex area.

JEL Keywords: L93 air transportation, R41 congestion

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1 Introduction

The continuous growth of air traffic is rapidly bringing the National Airspace System (NAS) to congestion levels that are negatively affecting the level of service as well as safety and delays. These issues will increasingly affect future air transportation and commercial air services (Morrison and Winston, 2007, see). The Next Generation Air Transportation System (NextGen) is being developed to address the need to grow and accommodate up to three times the number of operations in today's system. The Joint Planning and Development Office (JPDO) and other federal agencies are working, together with FAA, to move forward the system (JPDO, 2007, see); the horizon of this is set to be the year 2025. Similar objectives have been targeted by EUROCONTROL through the Single European Sky ATM Research project (SESAR, 2007). Airport delays are extremely costly in terms of time lost by both business men and travelers. Airlines are also strongly penalized by the extra costs they face to pay their crews and operate their aircraft. Moreover, delay costs spillover to other industries that rely on air transportation, adding up to the overall costs from delays. The Joint Economic Committee estimated a total cost of 40.7 billion in 2008 caused by flight delays in 1100 airport in the NAS (JEC, 2008). Baik et al. (2010) estimate a total cost of 8.7 billion for 388 airports.

In days in which many airports operate at congestion levels, facing a continuously increasing demand, the call for a technological and structural improvement becomes more compelling for the global air transportation system. New technologies such as Data-Link communications, satellite navigation (GPS) and ATC decision support tools (DST) will be paramount in supporting the development of the system and the new demand levels and to alleviate level of congestion. The aim of this paper is to measure the economic benefit of introducing the new communication technology known as Controller Pilot Data-Link Communications (CPDLC) or Data-Communication on the three airports of LaGuardia, Newark, John F. Kennedy and on the metroplex area of New York. This area is one of the most congested in the NAS and these airports experience massive amount of delays every year. Moreover, previous studies have proved that delays propagate from the more congested airports to the rest of the system (Diana, 2009). So far, these studies analyzed some of the benefits Data-Comm can provide if introduced into the NAS, but most of them were focused on the benefits for only one particular class of stakeholders', i.e. the FAA(FAA, 1995, 1996) and the airline industry (C/AFT, 1999, 2000).

To our knowledge there are no studies that look at the benefit of Data-Comm introduction for both airport authorities and passengers. In this paper we try to estimate a meaningful, global measure of the economic benefit of the new technology from the perspective of an operation planner or policy maker, who takes into account the potential benefit for all the stakeholders, including airport authorities as well as airlines and passengers. The Re-Organized ATC Mathematical Simulator (RAMS) was first used to evaluate the impact of the new technology on airport operations. The simulation was run in one of the FAA average representative days of 2006 (February 23rd) on the three airports of LaGuardia, Newark and John F. Kennedy, with and without the new technology. Three sets of results were found for each of the three airports: " practical " and " maximal " capacities, in terms of hourly operations; a trade-off function that maps the number of (hourly) operations to average minutes of delay; the average workload of air traffic controllers in terms of minutes worked per hour.

We then used the data from the simulation to compute the benefit for each of the airports and for the metroplex as a whole. As the new technology would allow for both a greater number of operations (at a constant level of delays)- or a lower level of delays (at a constant level of operations)- and a net effect on average hourly workload for traffic controllers, we employed a two steps procedure to elicit a meaningful benefit measure. First, we estimate a "benefit" function per number of hourly operations. Following previous literature (Morrison and Winston, 2008, 2007, see) we obtain our estimate of the delay cost by summing average aircraft operating costs, flight attendant costs and aggregate value of passengers' time costs per block hour. In particular, we focus this on the difference in average delays between the baseline and Data-Comm. Even the cost of traffic controller workload is calculated only in relative terms, as the change, relative to the baseline, in minutes worked an hour times the salary. Second, we consistently estimate the average daily benefit of the new technology. Since there is a lot of variation in the number of operations at different times of the day, we use the empirical distribution of hourly operations to find consistent weights; we can so distribute a given number of daily operations accordingly among the different hours, evaluate the benefit function found in step one at each hour, and sum up over the day. The benefit is then computed as the reduced cost from delays plus the net effect on controllers' workload due to implementation of the technology.

The two steps procedure is applied at each airport individually and to the metroplex area as a whole. As the computation of the overall benefit for the metroplex requires further aggregation of the data, we use two distinct assumptions and provide two different measures of the overall benefit for the metroplex. The first measure (NY1) is obtained by keeping airports' relative share of operations constant. The second measure (NY2) is found by optimally reallocating flights across the airports from the perspective of a benevolent authority treating the metroplex as a unique air transportation organizational unit. This is done by assuming that the three airports work at the same level of average delay (approximately equating the marginal benefit from the last flight).

The remainder of the paper is organized as follows. Section 2 provides a very brief a description of Data-Comm technology. In Section 3 we summarize the results obtained in the simulation. In Section 4 we derive the benefit function. In Section 5 we compute the average daily benefit for the three airports and for the metroplex. Finally in Section 6 we discuss our results and make our concluding remarks.

2 Data-Comm Technology

Data-Comm is a technology that adds a complementary medium of communication to the traditional voice data exchange (see Figure 1). This technology allows controllers and pilot to exchange a wide range of messages via data-link; these messages appear in coded form into a dedicated screen reducing the chances of miss-interpretations by controllers or pilots.

Many studies have been conducted by the FAA (FAA, 1995, 1996) and by NASA (Smith et al., 2004; Prevot. et al., 2007, see) to quantify the benefits of what is now called Data-Comm, previously referred to as Controller Pilot Data-Link Communications (CPDLC). All such studies agree in asserting that voice communication channels between controllers and pilots are close to saturation levels, and show how Data-Link communications would alleviate this problem and support increased traffic and new operation concepts. From this perspective it is relevant to consider the messages that can be exchanged through Data-Comm:

- Frequency changes
- Climb/descent clearances
- Direct clearances
- Turns and headings
- SSR instructions
- Replies to aircrew requests
- Microphone checks

These messages are already exchanged in the Maastricht Upper Area Control Centre in Europe(EUROCONTROL, 2010) and will be soon implemented in the NAS in USA(FAA, 2010). Data-Comm will contribute significantly to increased efficiency, capacity, and safety of the commercial air transportation operations. The evolution of Data-Comm in the operational environment will be based upon the incremental implementation of advanced communication capabilities. This represents the first phase of the transition from the current analog voice system to an International Civil Aviation Organization (ICAO) compliant system in which digital communication becomes an alternate and eventually predominant mode of communication.

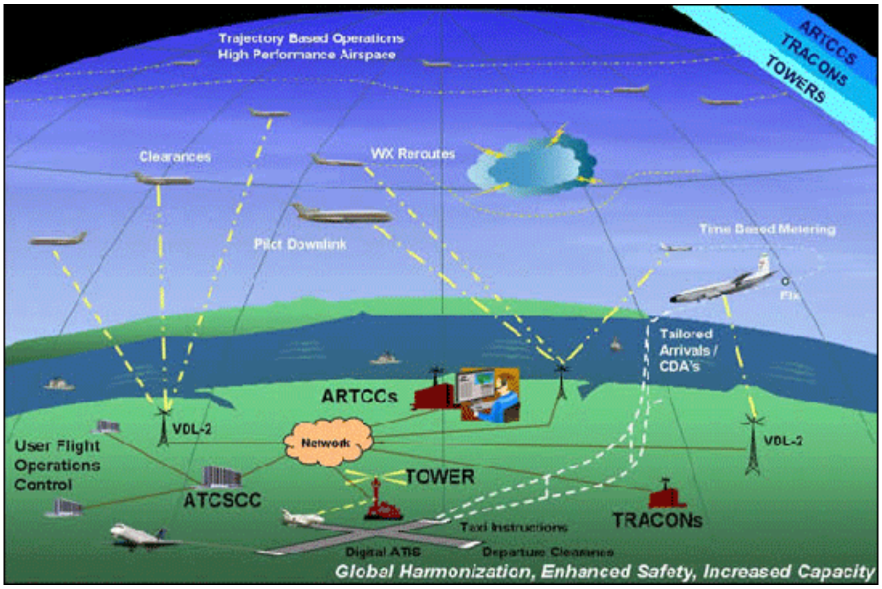
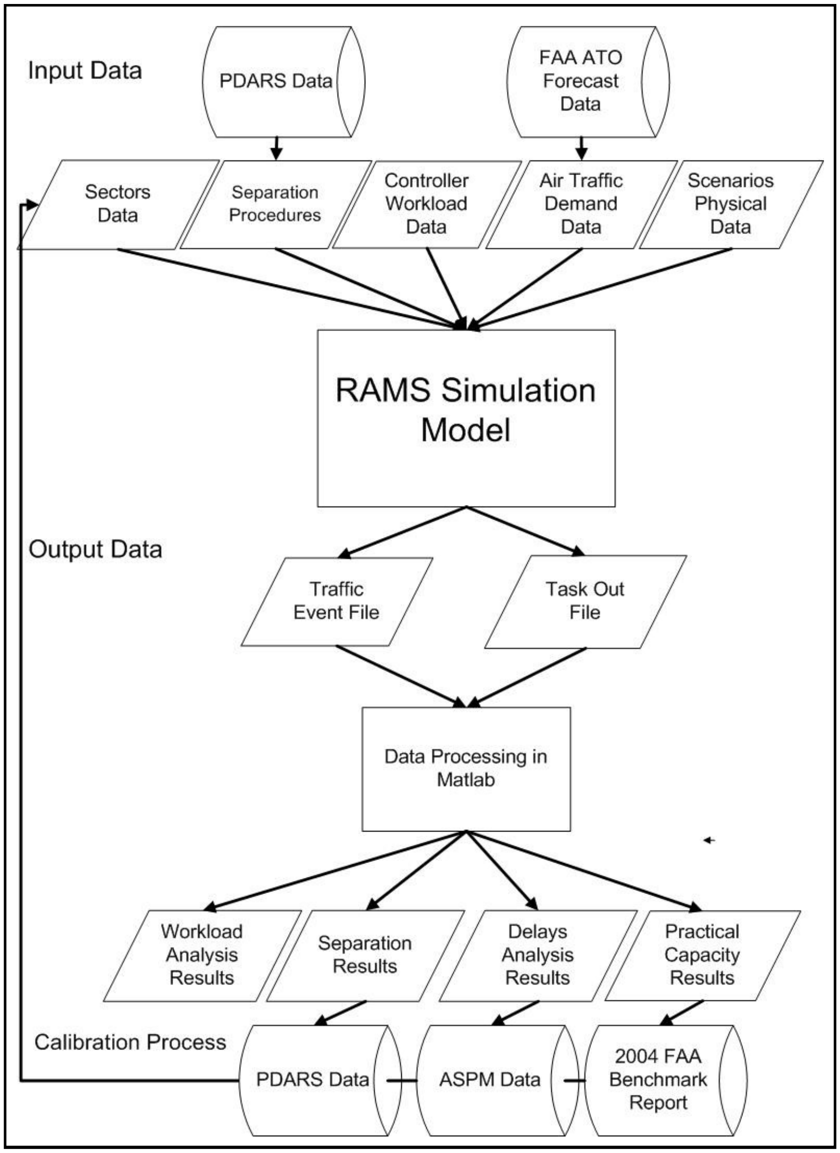


Figure 1: Data-Comm Concept of Operation

The benefits of this new communication paradigm are not only significant per se. What is most important is that Data-Comm represents a paramount technology enabler for more advanced new ATC capabilities, e.g. automated conflict detection and resolution, trajectory based operations and continuous descent approaches. All these new concepts can be fully implemented only in a scenario with Data-Comm already in place. In fact, the necessary level of communication exchange cannot be carried out only via voice.

Finally, the introduction of Data-Comm will lead to the automation of many repetitive tasks, allowing supplement voice communications with less workload-intensive data communications and enabling ground systems to use real-time aircraft data to improve traffic management efficiency. As the fast time simulation we carried out (Enea et al., 2009, see) proved, the operations enabled by Data-Comm will allow air traffic controllers to manage more traffic and increase the capacity of the NAS, reducing operational costs for airspace users and the FAA.

Figure 2: Simulation Model Flowchart



3 RAMS Simulation Operational Benefits

This paper relies on the results of Enea et al. (2009) that demonstrated how Data-Comm technologies could yield some performance increases for airports and terminal area airspace. Operational benefits in terms of total delays experienced by each airport were analyzed using RAMS simulation software. Furthermore, reduced workload for air traffic controllers was recorded with the new communication protocol implemented.

Overall a modest gain in the hourly capacity was found. However, as we will show in the next section even a modest gain might result in significant cost savings. Figure 2 shows the flowchart of this simulation. The simulation was run using the traffic schedule of February 23rd 2006 on the airports of LaGuardia, Newark and John F. Kennedy. This day was selected by the FAA as one of the representative average traffic days of 2006. For the capacity analysis a fictitious flight schedule was created ad hoc, to increasingly simulate the capacity performance, in terms of hourly arrival and departure rates, of each airport analyzed. The introduction of Data-Comm was simulated tweaking two parameters in the simulation: the Miles-In-Trail separation (MIT) and the values of the minimum separation matrix.

The MIT separation controls the aircraft distance in the final approach flow: during the simulation it was reduced from 9 miles (baseline), to 8 and 7 miles[1]. The separation matrix controls the minimum separation after take-off and is applied by controllers to impose wake vortex safe separations; under the new technology the separation matrix was reduced by 5% from the baseline values. The choice of these two parameters, and their respective values, originate from a previous NASA human-in-the-loop simulation study (Smith et al., 2004). This makes the simulation extremely meaningful, as the difference between the two scenarios is given not by arbitrary stochastic components, but rather by a set of different rules that will most likely be applied. The simulation study was divided in three separate analyses: airport capacity by airport in the metroplex area, delay levels and air traffic controllers' workload.

3.1 Airport Capacity

A new methodology was applied to evaluate the hourly operations practical capacity envelope of LaGuardia, Newark and JFK. The capacity envelope represents the maximum number of arrivals and departures an airport can process in a hour. For each airport three operational scenarios were simulated, each using different settings of MIT and departure separation matrix. The three scenarios were the baseline actual opera-

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[1] The choice of two different measures relies on the incremental implementation of the new technology discussed in section 2. For the computation of the economic benefit though, we use all results from the full implementation (Data-Comm 2, see below).

Table 1: Capacity benefit summary

	LGA			**EWR**			**JFK**		
Benefit	**Arr**	**Dep**	**Mix**	**Arr**	**Dep**	**Mix**	**Arr**	**Dep**	**Mix**
	3%	4%	5.5%	1.7%	22%	11.7%	0%	27%	8.6%

Notes: Data used in the simulation were provided by the FAA, Air Traffic Organization Office. The simulation was run using the traffic schedule as of February 23rd on the airports of LaGuardia, Newark and John F. Kennedy.

tions and two incremental levels of Data-Comm: Data-Comm 1 and Data-Comm 2[2]. To evaluate the practical capacity of operations per hour that could be processed with the implementation of Data-Comm technologies an ad hoc analysis was modeled by creating an artificial demand based on the real aircraft mix actually operating at each airport. The demand (aircraft landing and taking off) was gradually increased to evaluate the number of acceptable operations manageable with a tolerable level of delay. The practical capacity was obtained when the level of delay reached the 5 minutes per operation threshold; this threshold is consistent with previous airport planning studies.

Three operational sub-scenarios were simulated to construct the capacity envelope: arrivals only, departures only and 50/50 percent arrivals and departures for Newark Liberty (EWR) and LaGuardia (LGA) Airports. For John Fitzgerald KennedyAirport (JFK) points across two levels of capacity were evaluated. JFK was simulated with "arrivals only" and "departures only" on a single runway; the independency of the operations between runways made this a reasonable assumption. The results for a single runway were then doubled to obtain the total value. For the "mixed operations" analysis the complete runway configuration was simulated.

The results showed interesting capacity gains in the three airports. Benefits from the introduction of Data-Comm were higher for the departure capacity (see Table 1). The highest benefit was obtained at JFK with an improvement from the baseline scenario of 25% for departure only operations. The high number of heavy aircrafts operating at JFK benefitted of the reduced wake vortex separations applicable with Data-Comm technology. Also EWR presented an increased departure capacity compared to the baseline (22%). The airport with the lowest improvement was LGA; this result is due the aircraft mix operating at this airport, mainly light and medium aircrafts. Moreover the runway configuration at LGA with two intersecting runway operating alternatively did not allow any significant capacity improvement. The highest benefits were registered for JFK, with a reduction of the delays from the baseline scenario to Data-Comm 2 of 40.3%. Detailed results for JFK are shown in Table 2.

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[2] The FAA plans to introduce Data-Comm into the NAS in incremental steps, two at a minimum.

Table 2: Summary of JFK delays (daily minutes)

Year	Flights	% Δ Flights	Baseline	Data-Comm	% Benefit
2006	1,009		4.64	2.77	-40.3 %
2014	1,351	34	28.87	16.21	-39.7 %
2,022	1,550	54	88.92	59.15	-33.5 %
2,025	1,588	57	217.89	94.47	-56.6 %

Notes:
Data used in the simulation were provided by the FAA, Air Traffic Organization Office. The simulation was run using the traffic schedule as of February 23rd on the airports of LaGuardia, Newark and John F. Kennedy.

3.2 Average Delays

The analysis of airports' delays highlighted how the three New York's airports are already operating close to their saturation capacity and how the level of delays will soon become intolerable without any struxtural and technological improvement. Four levels of demand were simulated in RAMS. The demand on the baseline year of the study 2006 and the predicted levels of demand for the years 2014, 2022, and 2025[3]. Although comparable, the results were quite different across airports. Table 2 presents a summary of the results. The simulation with two runways for arrivals (31L and 31R), and one for departures (31L) showed that in 2025 the average delay per flight would be more than 200 minutes. The level of delays would be considerably high also in 2014, with an increment of 34 percent and 26.87 minutes per flight. With the full Data-Comm implementation the benefit achievable would be quite significant. The reduction from 4.64 to 2.77 minutes per operation represents more than 40 percent of improvement. On the other hand, even with Data-Comm in service, 2022 and 2025 demands could not be served with an acceptable level of delays (see Table 2. From the analyses of airport capacity and delays we were able to fit a a trade-off function that maps the number of (hourly) operations at each airport to average minutes of delay. This function was then used as the starting point of the economic analysis to evaluate the impact of Data-Comm in the New York metroplex area.

3.3 Workload Analysis

The last analysis performed on the New York City Metroplex area, was on the impact and benefits of Data-Comm technologies on controllers' workload. As we already mentioned, the implementation of Data-Comm on the FAA's plan will be introduced in (at least) two phases. A step-by-step implementation approach for new concepts is always

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[3] We use the predictions by the FAA's Air Traffic Organization (ATO) office.

required in a sensitive field like controller-pilot communications. To take this into account, RAMS simulation followed the double objective of the project: reducing delays and controllers' workload at the The controllers' workload was simulated in RAMS by gradually reducing the weights of communication related task's from the baseline scenario to the second phase[4].

A total of 33 sectors were simulated in the New York airspace. For each sector RAMS assumes four controllers, two tactical and two strategic. A total of 132 controllers were simulated. RAMS by default has a list of 52 tasks that contribute to the calculation of the controllers' busy time; these tasks are divided in 5 categories. The tasks in the "Communication Activities" were gradually reduced from the baseline to phase 1, and finally to phase 2, in order to simulate the reduced time necessary to perform them with the implementation of data-link communications.

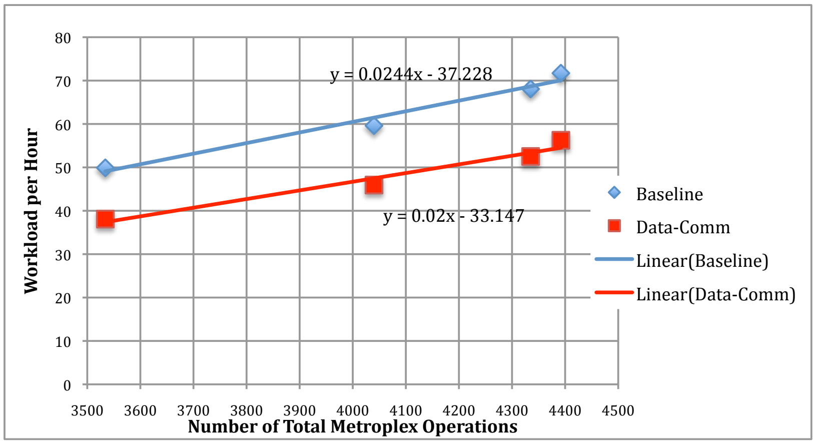

Figure 3: Linear Relation between the total number of operations and controllers' workload

The benefit of the new communication protocol was evaluated calculating the total busy time for each scenario. The occupation time per hour went from 49.9 minutes in the baseline, down to 38.9 with Data-Comm 2. The simulation was run at the different demand levels mentioned above. In 2014 the busy time would reach the 59.6 minutes per hour, a level not acceptable at all especially for continued period of time. With the full implementation of Data-Comm technologies the actual level of workload

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[4] Again, the choice of the tasks reduced were extrapolated from previous FAA studies(FAA, 1995, 1996).

would be reached with 2022 demand. The workload analysis followed the approach used by a previous European study (EUROCONTROL, 1999). Using the results of the simulation we were able to fit a linear relation between number of operations (see Figure 3) and busy minutes at the metroplex level. We then included this measure of workload benefit in the computation of the overall benefit measure.[5].

4 The Benefit Function

The benefit of implementing the new technology can be evaluated starting from the gains in terms of delays reduction per number of hourly operation. In our first step we estimate a benefit function using our data on average delays and number of operations. More formally, we use the simulation results to build a function that maps average aircraft delay to number of operations for each airport. We computed this relationship both in the baseline scenario and with the adoption of the new technology. The function has the following form

$$y_i(x) = \alpha_i e^{\beta_i x} \tag{1}$$

where $i = 0, 1$ denotes the adoption of the new technology, and x and y denote respectively, the number of hourly operations and the average aircraft delay. The vertical distance between the Data-Comm and the baseline functions gives us the net benefit in terms of average delay per operation as a function of hourly operations

$$\Delta y(x) = \alpha' e^{\beta' x} = \alpha_0 e^{\beta_0 x} - \alpha_1 e^{\beta_1 x} \tag{2}$$

To translate delays in aircraft operations into costs (and their difference into dollar benefits) we use a cost measure per aircraft block-hour following previous literature. We compute the hourly benefit deriving from the new technology at level of operations x, equal to

$$B_h(x) = \Delta y(x) \cdot x \cdot \{\mathcal{BHC}_m + \mu_{ps} \cdot \mathcal{FAC}_m + \mu_{ps} \cdot \mathcal{LF} \cdot \mathcal{PTV}_m\}. \tag{3}$$

In our formulation, the cost of flight delays is equal to the average minutes of delay times the number of operations multiplied by the average aircraft operating costs per block hour ($\mathcal{BHC}$) plus the flight attendant costs ($\mathcal{FAC}$) per block hour times the average number of seats per flight (μ_{ps}), plus the aggregate value of passengers average time costs per hour ($\mathcal{PTV}$). The number of passengers is calculated as the number of seats times the average load factor ($\mathcal{LF}$). The h subscript on $B_h(x)$ is to highlight

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[5] The demand simulated in RAMS is relative to February 23 2006, therefore the same day in FAA ASPM database was used to compare the results and validate the simulation. In terms of delays, JFK gave the best fit between the simulated results and the real data both in magnitude and in the trends. For more details on the simulation see (Enea et al., 2009)

the fact that we are dealing with an hourly benefit, the m subscript on all other parameters indicates that we are considering their minute value. We base our cost computation on the values reported by Morrison and Winston (2008), who estimate, using US Department of Transportation Form 41 database and the (DTO, 1995, 1997), a median aircraft operating cost per block-hour (\$3,038), a flight attendant costs per seat-hour (\$3.13) and the median value of passengers‘ time cost (\$54.58)[6] . We estimate the average number of seats per aircraft as the weighted average of seats over all the flights operating the day of the simulation in the three airports (see Table 3) in standard two class configuration. The average load factor reported from IATA is 0.81 for North America(IATA, 2010).

The benefit from reduced traffic controller workload is calculated only in relative terms, as the change, relative to the baseline, in minutes worked an hour times the salary. To compute this benefit we consider the number of controllers working in each sector and the structure, by sectors, of the New York metroplex airspace, to obtain a measure of total minutes worked an hour in each airport and on the metroplex as a whole. The difference in minutes, times the average minute salary gives us the net effect. The New York Area is divided in 33 Air Traffic Control Sectors, and in each of these sectors there are four air traffic controllers. While sectors operate independently from airports and the simulation for controllers' workload was run at the metroplex level, we were able to assign respectively 13, 10 and 10 sectors to the airports of JFK, LGA and EWR, making a total of 52, 40 and 40 controllers.

The simulation on workload uses a similar approach to a previous European study (EUROCONTROL, 1999) and computes the technology impact on the hourly controller occupation time. In line with approach is the choice of the salary to compute the value of controllers work. The salaries in fact a proxy for the true value lying betweens the airport authority's willingness to pay (WTP) and the controlers' willingness to accept (WTA). The vertical distance between the two functions in Figure 3 gives us the reduced number of minutes worked in one hour by each controller for a given number of operations x. We use the 75th percentile minute salary for air traffic controllers in the US to account for experience by controllers in New York[7] . Being simulation results hourly averages of day simulation we compute the relative daily benefit by the technology on controllers' workload $\Delta\mathcal{W}(x)$ as

$$\Delta\mathcal{W}(x) = w \cdot \Delta L_{min}(x) \cdot \mathcal{ATC} \cdot 24 \tag{4}$$

where w, $\Delta L_{min}(x)$ and $\mathcal{ATC}$ denote, respectively, the wage, the difference in minutes worked an hour, and the (relevant) number of air traffic controllers.

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[6] All the values are expressed in 2010\$

[7] We use 69.13 \$ as hourly wage, based on 75 percentile distribution of controller wages

Table 3: Weight, Passengers and Number of Operation (23 February 2006)

Aircrafts	NY	LGA	ERW	JFK
Average Weight	168,515	107,683	161,586	250,565
	(1,915)	(1,483)	(2,726)	(4,861)
Average Passengers	130.6	95.89	124.0	180.8
	(1.142)	(1.101)	(1.592)	(2.823)
Observations	7,038	2,410	2,620	2,008

Standard errors in parentheses

Notes:
Data reported in Table 3 were computed using standard two class configuration by model and average weight (pounds).

5 Data-Comm Average Daily Benefit

To compute the average daily benefit for each of the three airports and for the metroplex as a whole we use the empirical distribution of hourly operations by airport and the benefit function derived in section 4. Using the data on hourly operations observed in the three airports during the day of the simulation we get weights:

$$s_{jh} = \frac{N_{jh}}{\sum_{h=1}^{24} N_{jh}} \tag{5}$$

where N_{jh} is the number of operations at Airport j in hour h. Let x and x_j denote, respectively, the number of operation in the entire metroplex and at airport j; we can easily find $x_j = x \cdot N_j/N$. We redistribute flights at airport j across different hours of the day by setting $x_{jh} = x_j \cdot s_{jh}$. We can so compute the average daily benefit at airport j and level of operation x as the sum over the hours of the day of the benefit $B_{jh}(x_{jh})$ plus the net effect on controllers workload at airport j and operations x. Formally, the average daily benefit is equal to

$$\mathcal{ADB}_j(x) = \sum_{h=1}^{24} B_{jh}(x_{jh}) + \Delta\mathcal{W}_j(x) \tag{6}$$

where the subscript j on $\Delta\mathcal{W}_j(x)$ denotes that the effect on workload is calculated on airport j. For the metroplex as a whole we provide two distinct measures of average daily benefit. As the computation of the overall benefit for the metroplex required further aggregation of the data, we used two distinct assumptions. The first measure (NY1) is obtained by keeping airports' relative share of operations constant. The second measure (NY2) is found by optimally reallocating flights across the airports from the perspective of a benevolent authority treating the metroplex as a unique air transportation organizational unit. This is done by assuming that the three airports work at the same level of average delay (approximately equating the marginal benefit from the last flight). The higher benefit on the overall area is explained (see Table 4, col. 6) by the fact that in this second measure airports are assumed to work at the same level of average delay. Re-equilibrating the distribution of delays across New York airports will in fact reduce the amount of delay in JFK with respect to EWR and LGA. As the benefit from the new technology is lower in the airport experiencing the highest delays (JFK), equating the average delay across airports has the effect of increasing the daily benefit, since it reduces the number of flights where the benefit is lower and increases the number of flights where the benefit is higher. Along with the difference between the two measures, an optimal reallocation of flights would yield a second beneficial effect deriving from the optimal redistribution of flights across the three airports. The effect would be similar to that of redistributing flights more evenly between peak and non-peak hours within an airport. A careful reader might argue that different airplanes have different impacts on delays, making this assumption somehow incorrect; but as the marginal effect on delays depends on aircraft passenger capacity, if a difference exists, it should not be significant.

We compute the average daily benefit starting with 3,500 operations, and increasing this numbers by 100 up to 4400 operations (see Table 4). The gains are significant in all the three airports, ranging from 225,783$ at JFK to 331,173$ at EWR when we consider 3,500 operation (substantially identical to the 3,519 operations that in the traffic schedule of February 23rd 2006 - date analyzed in the simulation study - on the airports of LaGuardia, Newark and John F. Kennedy). When we look at the overall New York area the benefit ranges from 851,910 $ when we use the actual airport delays (NY1) to 1,053,217 $ when we equatethe average delay across airports. In a year Data-Comm would yield a saving ranging between 310 millions (NY1) and 384 millions (NY2) depending on the assumptions we make about the distribution of delays across airports. It is worth noting, that even if the benefit is increasing in the number of operations, our measure is only relative. A huge number of operations in fact, imposes an enormous cost under both scenarios. Without any structural improvement, none of the hubs studied could sustain any significant improvement in demand, with or without Data-Comm. All of the airports analyzed in the New York Metroplex area are in fact close to their saturation capacity levels. Table 5 describes the hourly benefit across the three airports. As we can see the introduction of Data-Comm would have an immediate impact on hourly costs ranging from 9,240$ in EWR to 10,296$ in LGA. The marginal benefit of the new technology is increasing in the number of operations and runs up when the air-traffic reaches the airport practical capacity.

Table 4: Average Daily Benefit

Operations	LGA	EWR	JFK	NY(1)	NY(2)
3,500	294,954	331,173	225,783	851,910	1,053,217
3,600	317,893	357,332	234,143	909,368	1,104,514
3,700	342,378	385,317	242,615	970,310	1,157,413
3,800	368,508	415,253	251,202	1,034,962	1,211,960
3,900	396,389	447,273	259,903	1,103,566	1,268,201
4,000	426,135	481,521	268,722	1,176,377	1,326,187
4,100	457,865	518,147	277,659	1,253,670	1,385,965
4,200	491,706	557,313	286,716	1,335,736	1,447,589
4,300	527,795	599,194	295,894	1,422,883	1,511,110
4,400	566,275	643,973	305,195	1,515,442	1,576,584

Notes:
Data used in the simulation were provided by the FAA, Air Traffic Organization Office. The simulation was run using the traffic schedule as of February 23rd on the airports of LaGuardia, Newark and John F. Kennedy. We compute the cost of delay as defined in equation 3 using the cost estimates reported by Morrison and Winston (2008), based on US Department of Trasportation Data, and data on controllers‘ salaries provided by the FAA. Results in 2010 US dollars.

6 Concluding Remarks

The aim of this paper was to find a meaningful global measure of the economic benefit of the new technology. A few considerations led us to the choice of using an average daily benefit, summing the two effects on delays costs and controllers' workload. As the new technology allows for both a greater number of operations (at a constant level of delays), and a lower level of delays (at a constant level of operations) a possibility was to find the optimal number of operations by the airport authority or a benevolent planner under

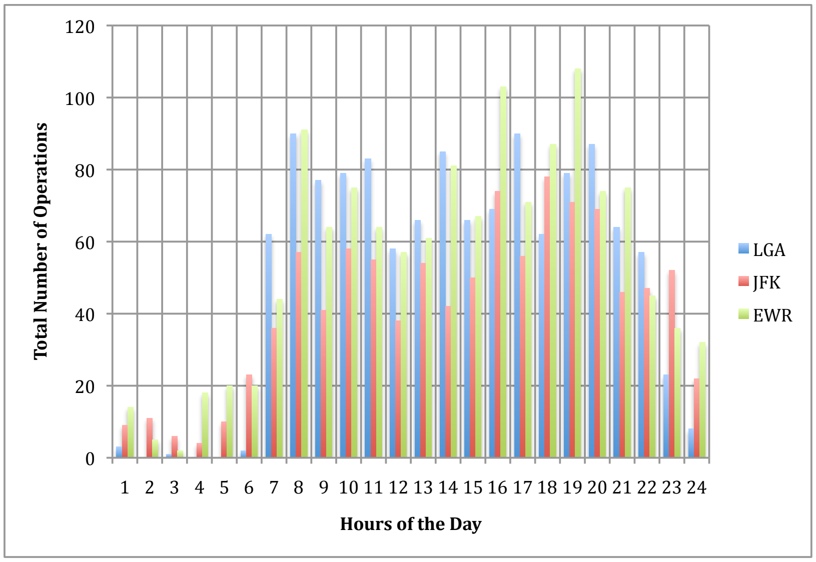

Figure 4: Total Number of Operation across NY Airports

the new technology. Such a computation though raises many problems (consumers demand, airlines supply, the market for airport slots), and is implausible given the defnition of practical capacity (i.e. there is a tolerable level of delays that should not be passed). We take a different route instead, ignoring the effect on the number of slots. We compute a measure that is flexible and can be adjusted at different levels of demand. We find that the introduction of Data-Comm would yield significant savings in the New York Metroplex area. However, it is worth noting, that even if the benefit is increasing in the number of operations, our measure is relative to the baseline. A huge number of operations in fact, impose an enormous cost for both scenarios. Without any structural improvement, none of the hubs studied could sustain any significant improvement in demand, with or without Data-Comm. The current use of practical capacity has a direct impact on the average delay per hour and consequently on the delay costs. We provide evidence of significant potential gains from the Data-Comm implementation in the three airports and in the overall New York Metroplex area. This suggests that the introduction of this new technology might be crucial to face expected increases in the demand that might substantially raise delays and costs in the next years. The new technology would allow for a greater number of operations and reduce the average hourly workload for air traffic controllers.

Table 5: Data-Comm Hourly Benefit Across NY Airports

Number of Operations	LGA	EWR	JFK
55	10,296.06	9,240.29	9,263.68
60	12,538.11	11,252.44	10,361.66
65	15,162.36	13,607.59	11,509.30
70	18,227.36	16,358.30	12,708.40
75	21,800.15	19,564.73	13,960.84
80	25,957.36	23,295.66	15,268.54

Notes:
Data used in the simulation were provided by the FAA, Air Traffic Organization Office. The simulation was run using the traffic schedule as of February 23rd on the airports of LaGuardia, Newark and John F. Kennedy. We compute the cost of delay as defined in equation 3 using the cost estimates reported by Morrison and Winston (2008), based on US Department of Trasportation Data, and data on controllers' salaries provided by the FAA. Results in 2010 US dollars.

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