REGIONAL AIRPORT SYSTEM PLAN UPDATE –
BASELINE RUNWAY CAPACITY AND DELAYS REPORT

Prepared for:

Regional Airport Planning Committee

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1. INTRODUCTION

1.1 Project Overview

The Regional Aviation System Plan (RASP) serves as the San Francisco Bay Area's overall policy document for aviation planning by identifying the region's future airport demand and capacity needs and articulating strategies for accommodating future aviation demand. The goals of this Regional Airport System Planning Update are to:

- Identify and analyze the effectiveness of alternative strategies for accommodating the Bay Area's long-term aviation demand without constructing additional runways at the primary airports;
- Involve stakeholders and the public to aid in building a regional consensus on how to respond to congestion at the primary Bay Area airports; and
- Assist the Regional Airport Planning Committee (RAPC), an advisory committee to the Metropolitan Transportation Commission (MTC), the Association of Bay Area Governments (ABAG) and the Bay Conservation and Development Commission (BCDC), in developing a vision and implementation plan for the region's aviation system.

To accomplish these goals, the current study must address three critical questions:

- What are the capacity limits of the primary Bay Area airports?
- When are these capacity limits likely to be reached?
- What strategies offer the greatest potential to allow the region to efficiently accommodate future aviation demand?

1.2 Role and Scope of the Baseline Capacity Analysis

The purpose of the baseline capacity analysis is to determine when each of the primary airports will reach their airfield capacity limits. Airfield capacity for each of the primary airports was estimated for the base year (2007) and each future analysis year (2020 and 2035). Together airfield capacity and demand, as measured by actual and forecast aircraft operations, determines airfield delay hours for the base year and forecast years. It is important to note that the baseline capacity analysis only considers airfield constraints.

The results of the baseline capacity analysis will ultimately serve as the basis for assessing the capacity enhancing benefits of the various alternative strategies that will be analyzed in the Target Analysis. These include the implementation of High Speed Rail (HSR), redistribution of traffic among the primary airports, greater use of secondary airports, the deployment of new air traffic control (ATC) technologies, and potential demand management strategies. The airfield delays associated with the implementation of each strategy will be measured against the baseline delays to determine the effectiveness of each potential strategy.

The capacity and delay analysis considered all operations at each airport, including commercial airline and general aviation flights, since they may share the use of runways and are managed together by the FAA. The analysis was focused solely on runway capacity and delays. Airspace or landside constraints were not included in the capacity analysis. Only airspace issues within the immediate vicinity of the airport were considered. Additional airspace modeling would be needed to further evaluate the extent to which airspace interactions would affect airport system capacity. The modeling reflects existing conditions and does not consider potential airfield improvements or ATC enhancements.

All assumptions and parameters were developed with input and consultation from the FAA and airport personnel. The consultant team reviewed existing studies and interviewed FAA personnel at the Air Traffic Control Towers (ATCT) for each airport as well as the (NORCAL TRACON) to identify the patterns of runway use and major constraints at each airport. The consultant team also coordinated with airport planning and operations personnel who provided guidance and critical data inputs. Airport personnel also reviewed and provided valuable comments on the final results. Finally, the methodology and assumptions were presented and discussed in a technical Working Group of experts convened by MTC.

2. METHODOLOGY

2.1 Overview

The runway capacities of the three major Bay Area commercial service airports have been extensively studied by the airports in the course of updating the airport Master Plans and by the FAA as part of its airport capacity benchmarking project and Future Airport Capacity Task (FACT) study. The consultant team reviewed these studies and supplemented them with visits to each airport and discussions with airport operations personnel and with FAA air traffic controllers.

Runway constraints fall into four areas: airport geometry (e.g., number of runways, lengths, orientation, and exits), operating procedures (e.g., ATC rules and instrumentation), weather (e.g., historical data on IFR conditions) and user characteristics (e.g., airline schedules and fleet mix). The constraints are summarized for all airports in the following report. The airport data were used to identify those runway configurations (i.e. combinations of runways and weather conditions) to be analyzed in this study.

The goal of the Regional Aviation System Planning Analysis update is to identify effective regional approaches for accommodating future aviation demand from a myriad of possibilities; it does not require the same level of modeling sophistication that projects such as an EIS may require. TAAM and SIMMOD are two detailed simulation models designed to examine the full range of airport activity including gates, taxiways, runways and airspace. These models require a considerable amount of effort to prepare the data for each airport and to validate the results. For this study the consultants have selected a more appropriate simulation model, Flexible Airport Simulation (FLAPS), which examines just runways and final approach. Compared to TAAM or SIMMOD, FLAPS is simpler to set up and it executes very quickly. The DELAYSIM model was then used to estimate runway use and delays based on the configuration capacities, hourly airport demand and 10 years of weather data.

Operational capacities for each runway configuration and weather condition were calculated using FLAPS with the appropriate aircraft fleet mix for the airport and analysis year. A separate hourly demand profile was calculated for jet and non-jet activity for an average weekday, Saturday and Sunday, using radar flight track data. Monthly adjustment factors were calculated from tower counts of aircraft operations.

Delays were calculated by DELAYSIM using 10 years of hourly weather data, the hourly demand profile for the relevant month and day of week, and the runway configuration with the highest capacity for the prevailing wind strength and direction, given the allowable tailwind and crosswind criteria. If the demand exceeds the airport capacity in any given hour then a queue forms and the unmet demand spills to subsequent hours. The delay in any given hour is assigned to the weather condition and runway configuration in effect for that hour.

Allowable tailwind and crosswind criteria are different for dry and wet runways. The runways were assumed to be wet if there was more than 0.01 inches of precipitation in the previous hour. However, this may sometimes overstate the duration of wet runway conditions and hence understate the runway capacity during the hour. Similarly, the average wind strength and direction from each weather observation in a given hour was assumed to remain in effect for the entire hour.

2.2 Capacity Model – FLAPS

The Flexible Airport Simulation (FLAPS), which FTA developed with the Flight Transportation Laboratory of the Massachusetts Institute of Technology, is an event-driven Monte Carlo simulation that models aircraft operations from the terminal entry fix[1] to the runway exit and from the runway departure queue to the departure fix. In this study, FLAPS is used principally to provide estimates of runway capacity. Model inputs include detailed representations of the three primary factors that affect capacity:

- Aircraft characteristics and fleet mix
- Runway layout and availability
- Air traffic control operating procedures

Fleet mix requirements include estimated number of operations by aircraft type. For computational efficiency, individual aircraft types are grouped into similar classes based on operating requirements and performance characteristics; these include runway lengths for takeoff and landing, engine types (jet versus propeller), and FAA aircraft weight classes. FLAPS utilizes eighteen aircraft classes (nine arrival and nine departure) with distinct operating characteristics including approach speed, float and braking distances, and departure runway occupancy time. The fleet mix affects runway capacity because different classes of aircraft have different runway occupancy times and in-flight separation requirements.

Runway layout input requirements include the orientation and length of each runway and the location and type (e.g., high speed) of runway exits and intersections.

Air traffic control inputs include a range of operational factors such as the runways in use at specified times and their modes (e.g., arrival only, mixed arrivals and departures, departure priority), runway assignment policy (e.g., by aircraft type, by direction of flight, etc.), and the required separations (arrival-arrival, departure-departure, departure-arrival) between successive aircraft operations under different weather conditions. Separation standards are a critical element of runway capacity calculations, and FLAPS is

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1 Each airport has several arrival fixes, which vary in distance from the airport but are typically around 25 nm out. These help ATC route arrivals from different origins to the landing runway approach path. In addition, each airport has a set of departure fixes to help ATC route the flow of takeoffs from the runways to the enroute environment.

uniquely designed to accurately apply appropriate separations for single runways as well as multiple intersecting or non-intersecting runways. FLAPS utilizes other air traffic control variables including the location of final approach fixes, land-and-hold-short operations, traffic distribution by arrival and departure fix, etc.

The combinations of physical runway layouts and air traffic control procedures are used to define various runway configurations. Each configuration consists of a single runway or set of runways in use and the air traffic control variables in effect at that time. In order for DELAYSIM to simulate operations accurately over the course of a year, every feasible runway configuration should be defined and its capacity estimated. Variations in air traffic control procedures, active runways, and weather conditions require subsets of the primary runway configurations. Due to budget constraints, the number of configurations examined in this study was limited to the most frequent operating situations at the three Bay Area commercial airports.

For this regional analysis , the primary output of each FLAPS model run is the saturation capacity of a runway configuration, with saturation capacity defined as the maximum number of aircraft arrivals and departures that can be achieved in one hour under given fleet mix, weather, and air traffic control conditions. Saturation capacity implies a high workload and no distractions for controllers, and it exceeds the level of activity that controllers can sustain for prolonged periods of time. Operational capacity, approximated as 90 percent of saturation capacity, represents the long-term operating levels which controllers achieve in practice.

2.3 Delay Model -- DELAYSIM

DELAYSIM is a unique model developed by FTA to simulate how air traffic controllers might use the airport’s runways based on specified demand characteristics and actual weather observations. It predicts hour-by- hour runway utilization, and estimates the associated aircraft delays.

DELAYSIM operates by sequencing through ten years’ of hourly weather observations and simulating the controllers’ selection of runway for each hour. It averages the results to produce annual operating statistics. For each hour, the runway selection is a three-step process. DELAYSIM first identifies from all possible runway configurations those which are available based on the wind, visibility and ceiling conditions. Second, the model identifies which (if any) of the available configurations has sufficient operational capacity to meet the demand in the current hour. If none of the configurations has sufficient capacity, the available configuration with the highest capacity is chosen. Third, if more than one configuration has enough capacity DELAYSIM selects the configuration that best meets the specified criteria which normally is based on airport noise goals, taking into account controller workload for runway changes. DELAYSIM also has the capability of selecting the available configuration with the maximum capacity in each hour, which normally would represent the controllers’ unconstrained preference. The maximum capacity option was used in this analysis.

Once DELAYSIM selects a runway configuration, it calculates delays by comparing the saturation capacity of that configuration with the projected hourly demand using a queuing theory model. DELAYSIM captures all delays in its statistics, not just those operations delayed by more than 15 minutes (although those delays are identified). In addition, DELAYSIM assumes that all scheduled demand will eventually be handled. In other words, DELAYSIM does not cancel operations, it simply delays them until they can be accommodated. For this reason, the hours of delay generated by DELAYSIM are not necessarily comparable to other models or FAA measures, and must be compared to a baseline condition to get a true measure of delay impacts. Stated another way, DELAYSIM includes the impacts of cancelled flights by estimating the additional delays that such flights would experience if they were to be completed.

In addition to producing delay statistics, DELAYSIM generates configuration utilization statistics that are used to evaluate changes in airport operational activity under different scenarios.

2.4 Estimation of Annual Airport Capacity

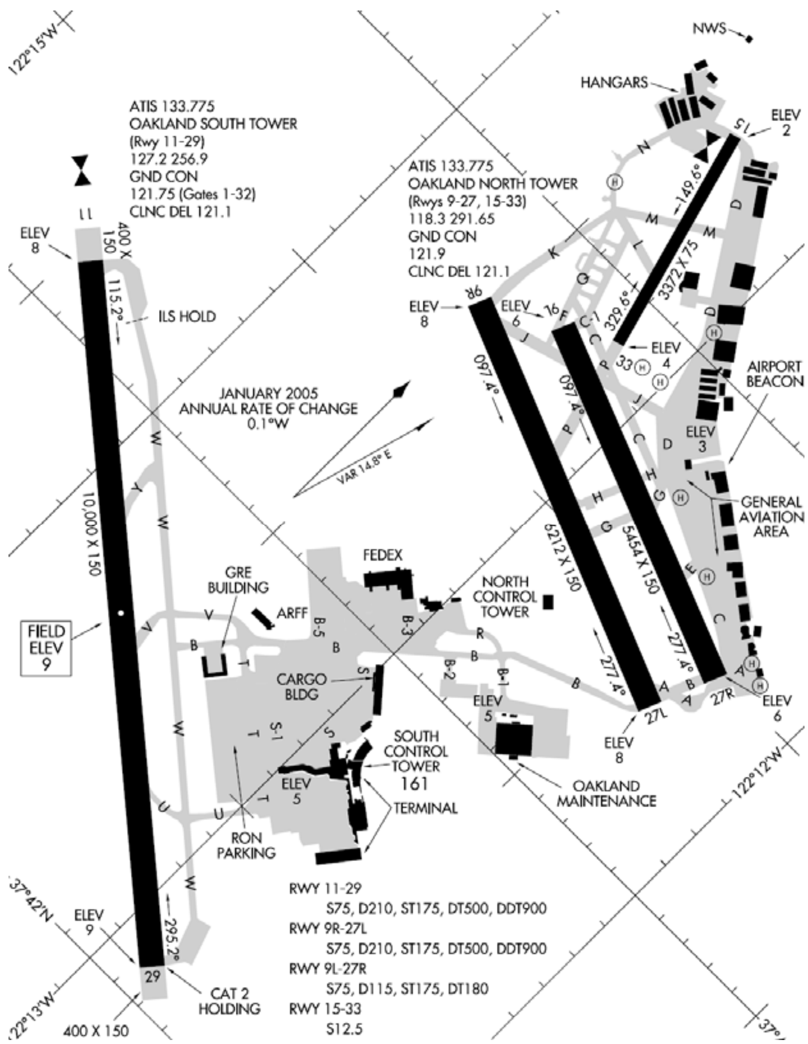
One of the objectives of the baseline capacity and delay analysis summarized in this report is to estimate when each airport might reach its practical annual capacity. Average delay per aircraft operation is a conventional metric for overall aircraft congestion. The FAA uses 15 minutes as a trigger point for reporting delays and this value is frequently used by airports for determining congested operations. However, the appropriate level of delay is really a policy decision for the airport operator, and it may vary depending on the type of activity at the airfield. For hub airports with international flights and longer turnaround times, the 15-minute average may be appropriate. But for airports with a high percentage of low-cost carriers which provide frequent service and require quick aircraft turnaround times, a lower value may be more appropriate. For this regional analysis, we have used a range of 12 to 15 minutes for all airports to estimate the level of operations that will constitute the airport's ultimate capacity.

3. METROPOLITAN OAKLAND INTERNATIONAL AIRPORT (OAK)

3.1 Airport Configuration

Oakland International Airport is unusual in that it has two somewhat independent elements: the South Field (Runway 11-29), which handles most of the commercial activity; and the North Field (Runways 9L-27R, 9R-27L and 15-33), which handles most of the general aviation (GA) flights as well as some cargo and air taxi operations. Nearly all of the commercial jet operations use the South Field, because of the longer length of Runway 11-29 while most GA jet operations to or from the west to use the South Field because of a local noise ordinance.

Exhibit 3-1: Layout of Oakland International Airport (OAK)



3.2 Runway Capacity

The FLAPS model, as described in Section 2, was used to estimate the runway capacity of OAK under various operating conditions. The following sections discuss modeling assumptions, the runway configurations modeled and the capacity results. The capacity analysis for OAK was based on the airfield layout, operating conditions and demand distribution for 2007. Although the Port of Oakland has examined a number of potential airfield and airspace improvements, none of these has been implemented and therefore, none were included in the analysis.

3.2.1 Fleet Mix Assumptions

The level of aircraft operations and the mix of aircraft types assumed for each analysis year is based on the actual and forecast activity data presented in the *Baseline Aviation Activity Forecasts* report for OAK. Actual aircraft activity for 2007 and forecast activity for 2020 and 2035 include general aviation, air passenger and air cargo operations at the North and South Fields. For the capacity analysis, operations by aircraft type were summarized into nine aircraft classes, which distinguish operations by aircraft size and airfield. (See Exhibit 3-2) Large jets, which have a maximum take-off weight between 41,000 and 255,000 pounds, account for an increasing share of the fleet at OAK, rising from 43 percent in the base year to 52 percent in 2035. Small propeller aircraft, which are projected to decline over the forecast period, account for 27 percent of activity in 2035 compared to 40 percent in 2007.

Exhibit 3-2: Summary of Base Year and Forecast Fleet Mixes for OAK

ID	Aircraft Class	2007	2020	2035
SP	Small props –North Field	40.1%	28.9%	26.6%
SJ	Small jets –South Field and/or North Field	3.0%	3.9%	4.2%
LP	Large props – North Field	1.0%	1.3%	1.2%
TP	Turboprops – South Field and/or North Field	0.9%	1.1%	1.1%
BJ	Business jets - South Field and/or North Field	2.6%	3.0%	3.6%
RJ	Regional jets – South Field	3.4%	4.0%	4.7%
LJ	Large jets –South Field	43.1%	49.3%	51.5%
5J	757s – South Field	0.8%	1.7%	0.3%
HJ	Heavy jets – South Field	5.1%	6.9%	6.9%

Notes: Small aircraft - ≤ 41,000 lbs
Large aircraft - >41,000 lbs and ≤ 255,000 lbs.
Heavy aircraft - > 255,000 lbs

Source:Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009.

3.2.2 Runway Configurations Modeled

Eight configurations, consisting of runway and weather condition combinations, were modeled for OAK to represent operations under east and west flow for three weather conditions:

- VAPS – good Visual Flight Rule (VFR) weather with ceilings at or above 4,500 ft and visibility at or above 5 nautical miles (nm).
- MVFR – marginal VFR weather below VAPS but with ceilings at or above 1,000 ft and visibility at or above 3 nm. Due to the fact that many GA flights in small aircraft do not operate in these weather conditions, forecast operations in small propeller aircraft were reduced to 40 percent of the VAPS levels in MVFR conditions.
- IFR – Instrument Flight Rule (IFR) conditions with ceilings below 1,000 ft or visibility below 3 nm. For normal Instrument Landing System (ILS) operations, ceilings must be at or above 200 ft and visibility above 0.5 nm. For west flow, two additional IFR configurations were included: ILS Cat II (with a minimum ceiling of 100 ft and visibility of 0.33 nm) and ILS Cat III (with a minimum ceiling of zero and zero visibility). Since most GA flights do not operate in IFR, the small props in the fleet mix were reduced to 5 percent of the VAPS levels.

West Flow – VAPS

For the west Flow-VAPS configuration the active runways are Runway 29 on the South Field and Runways 27L/27R on the North Field, all of which are modeled as mixed mode (both arrivals and departures). Although Runway 15-33 is also available for operations, it was not modeled since the 27L/27R runways have more than sufficient capacity for accommodating the GA demand on the North Field.

In this configuration, piston driven propeller aircraft are assigned to Runways 27L/27R for arrival and takeoff. Turbo-props and small business jets are allowed to use Runways 27L/27R or Runway 29. Large business jets can use any of the three runways for arrival, but are required to depart on Runway 29. All commercial jets use Runway 29 for arrival or takeoff. Standard IFR separations for single-runway arrival-arrival, arrival-departure and departure-departure operations were reduced for each runway in this configuration. Since pilots can see other traffic around them in good weather conditions, the standard IFR separation minimums can be safely reduced.

West Flow – MVFR

The runway assignments for the West Flow-MVR configuration are the same as the runway assignments for the West Flow-VAPS configuration, described above. For the West Flow-MVFR configuration, the arrival-arrival separations were increased to standard IFR values.

West Flow – IFR

For the West Flow-IFR configuration, piston-powered propeller aircraft depart on Runway 27L and arrive on Runway 27R. Turboprops and small business jets can arrive on Runway 27R or Runway 29, and depart on Runway 27L or Runway 29. Large business jets must depart on Runway 29 but can arrive on Runways 27R or 29. All commercial jets use Runway 29 for arrival and departure. Standard single-runway IFR separations were applied to each runway, and between Runways 29, 27L and 27R. The two additional West Flow-IFR configurations, the ILS Cat II and Cat III configurations, were adapted from another study which assumed increases in arrival-arrival separations and reductions in operations, since many small propeller-driven aircraft and some larger aircraft do not have the necessary instrumentation for operating in Cat II or Cat III weather conditions.

East Flow – VAPS

The active runways for the East Flow-VAPS configuration are Runway 11 on the South Field and Runways 09L/09R on the North Field, all of which are modeled as mixed mode (both arrivals and departures). Although Runway 15-33 is also available for operations, it was not modeled since Runways 09L/09R have more than sufficient capacity for accommodating the GA demand on the North Field.

For this configuration, piston driven propeller aircraft are assigned to Runways 09L/09R for arrival and takeoff. Turbo-props and small business jets are allowed to use Runways 09L/R or 11. Large business jets can use any of the three runways for departure, but are required to arrive on Runway 11. All commercial jets use Runway 11 for arrival or takeoff. Reduced single-runway arrival-arrival, arrival-departure and departure-departure separations were applied for each runway to reflect aircraft separations in good weather conditions.

East Flow – MVFR

The runway assignments for the East Flow-MVFR configuration are the same as the runway assignments for the East Flow-VAPS configuration, as described above. The arrival-arrival separations for the East Flow-MVFR configuartion were increased to standard IFR values.

East Flow – IFR

All arrivals use Runway 11 in the East Flow-IFR configuration. Piston powered propellers depart on Runway 09L. Turboprops and small business jets can depart on Runway 09L or Runway 11. Large business jets and all commercial jets must depart on Runway 11. Standard IFR departure-departure separations were applied to Runway 11; and between Runways 09L and 11. The arrival-arrival separations for Runway 11 were extended to provide time for 11 departures to taxi from the ILS hold point to the runway end.

3.2.3 Results

The results of the capacity analysis for each of the analysis years are shown in Exhibit 3-3. The values presented in the *Arrive*, *Depart* and *Saturation* columns are the maximum hourly throughput or saturation capacities for the airfield under balanced flow (i.e., equal numbers of departures and arrivals). The *Operational* column is 90 percent of the saturation capacity, based on the FAA's former method of estimating their Engineered Performance Standards for an airport. Generally, an airport's acceptance rate will lie between the theoretical Operational and Saturation capacities. For comparison, the current maximum arrival and departure acceptance rates at OAK, based on information provided by FAA's Northern California TRACON (NorCal), are shown in the final two columns.

Exhibit 3-3: Estimated Base Year and Forecast Runway Capacities for OAK

Year			Arrive			Depart			Capacity		NorCal	
2007	Flow	Weather	29	27L	27R	29	27L	27R	Saturation	Operational	Arr	Dep
	West	VAPS	26	19	13	31	14	14	117	105	58	80
	West	MVFR	27	7	3	27	5	5	74	67	35	80
	West	IFR	26		5	28	3		62	56	35	40
	West	Cat II	24			24			49	44		
	West	Cat III	22			22			43	39		
			11	09R	09L	11	09R	09L	Saturation	Operational	Arr	Dep
	East	VAPS	24	14	4	22	10	10	84	76	40	80
	East	MVFR	23	5	3	22	5	5	63	57	30	80
	East	IFR	25			20		5	50	45	25	40
2020			29	27L	27R	29	27L	27R	Saturation	Operational	Arr	Dep
	West	VAPS	26	15	8	32	9	9	99	89	58	80
	West	MVFR	27	4	3	27	4	3	68	61	35	80
	West	IFR	24		6	27	3		60	54	35	40
	West	Cat II	24			24			49	44		
	West	Cat III	22			22			43	39		
			11	09R	09L	11	09R	09L	Saturation	Operational	Arr	Dep
	East	VAPS	24	11	4	25	7	7	78	70	40	80
	East	MVFR	23	4	2	23	4	2	58	52	30	80
	East	IFR	24			21		4	49	44	25	40
2035			29	27L	27R	29	27L	27R	Saturation	Operational	Arr	Dep
	West	VAPS	27	14	7	31	8	8	95	86	58	80
	West	MVFR	27	4	3	26	4	3	67	60	35	80
	West	IFR	24		6	27	3		60	54	35	40
	West	Cat II	24			24			49	44		
	West	Cat III	22			22			43	39		
			11	09R	09L	11	09R	09L	Saturation	Operational	Arr	Dep
	East	VAPS	25	10	4	25	7	7	78	70	40	80
	East	MVFR	24	3	2	21	3	3	56	50	30	80
	East	IFR	25			20		5	50	45	25	40

3.3 Runway Delays

The DELAYSIM model, as described in Section 2, was used to estimate the runway delays. In addition to the hourly capacity inputs presented above, the DELAYSIM model also requires information on hourly weather observations, an hourly aircraft demand profile and the airport's wind rule.

3.3.1 Weather Assumptions

The delay modeling was based on 10 years of hourly weather data for the period 1998 to 2007. The hourly weather observations for OAK were obtained from the National Weather Service and included the following parameters as inputs to the DELAYSIM model:

- Date and time
- Wind speed and direction
- Ceiling
- Visibility
- Precipitation

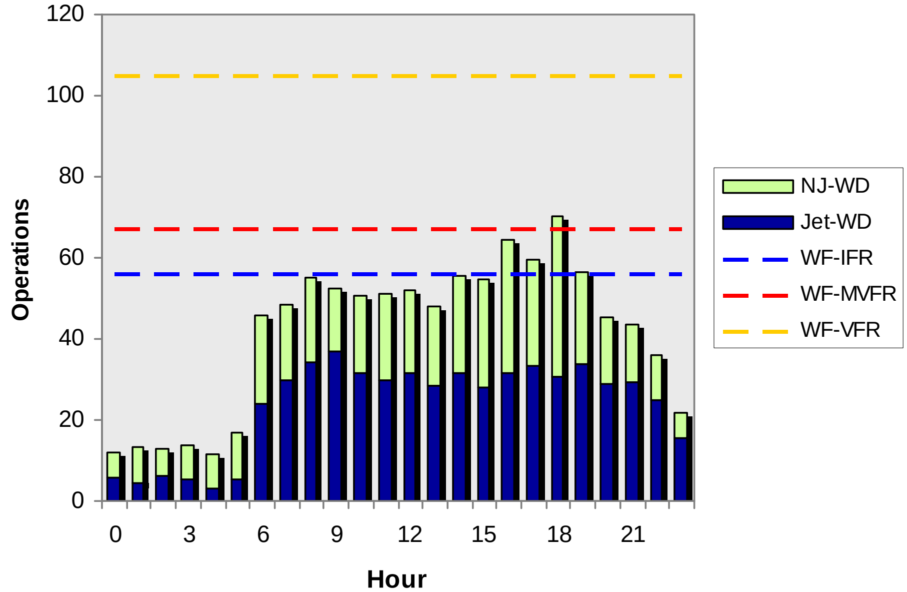
The weather data were processed to estimate missing values of some parameters, and to adjust the reported precipitation to the prior hour when it actually occurred. When more than one observation was reported in an hour, the average (wind speed and direction) or minimum (ceiling and visibility) was selected. In a few cases, where no weather observation was recorded, those hours were not modeled.

3.3.2 Hourly Demand Assumptions

The hourly distribution of aircraft demand is a key variable in estimating airfield delays. Radar tracking data for 2007 was used to estimate the hourly aircraft demand profiles for the base year. Separate profiles were developed for jets and non-jets, each for the average weekday, Saturday and Sunday. In addition, a monthly profile was developed to adjust the average profiles throughout the year. It should be noted that these profiles represent the total demand, including both arrivals and departures.

Exhibit 3-4 compares the jet and non-jet profiles for an average weekday in 2007 for both the North and South Fields combined. Exhibit 3-5 compares the total (jet plus non-jet) 2007 profiles for the average weekday, Saturday and Sunday. Exhibit 3-6 presents the variation in average demand by month of the year.

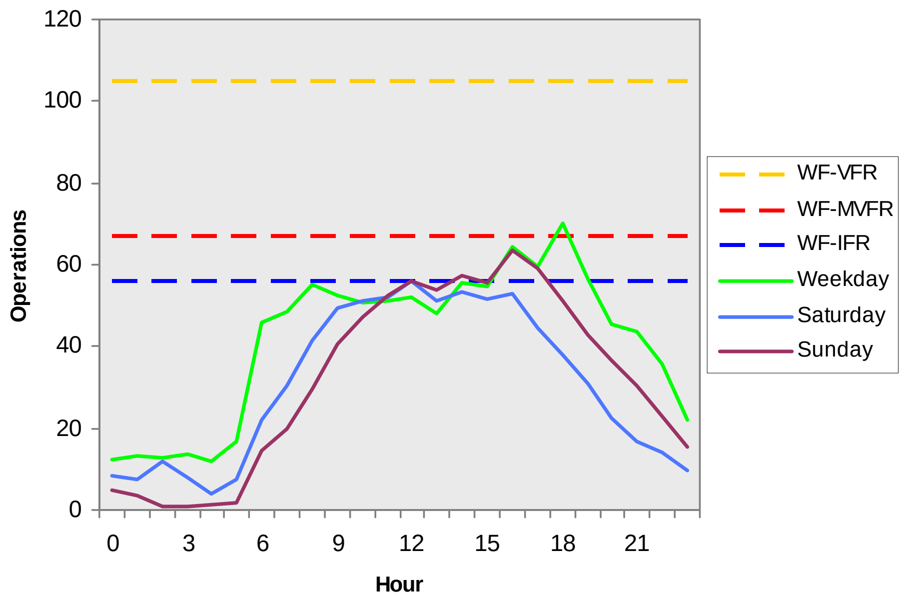
Exhibit 3-4: Jet and Non-Jet Operations per Hour at OAK, 2007 Average Weekday



Note: NJ-WD – non-jet weekday
Jet-WD – jet weekday

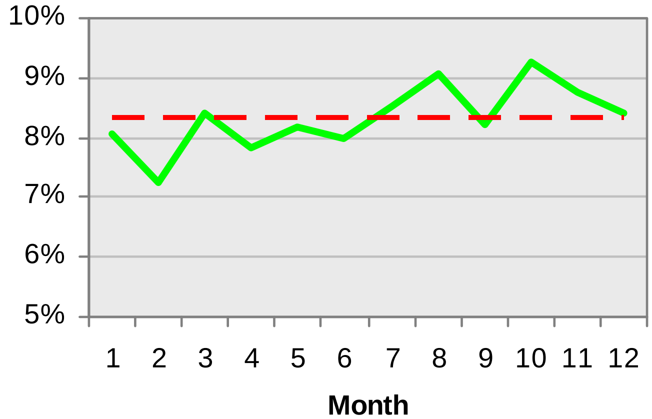
Source: Radar data.

Exhibit 3-5: Total Operations per Hour at OAK, 2007 Average Weekday, Saturday and Sunday



Source: Radar data.

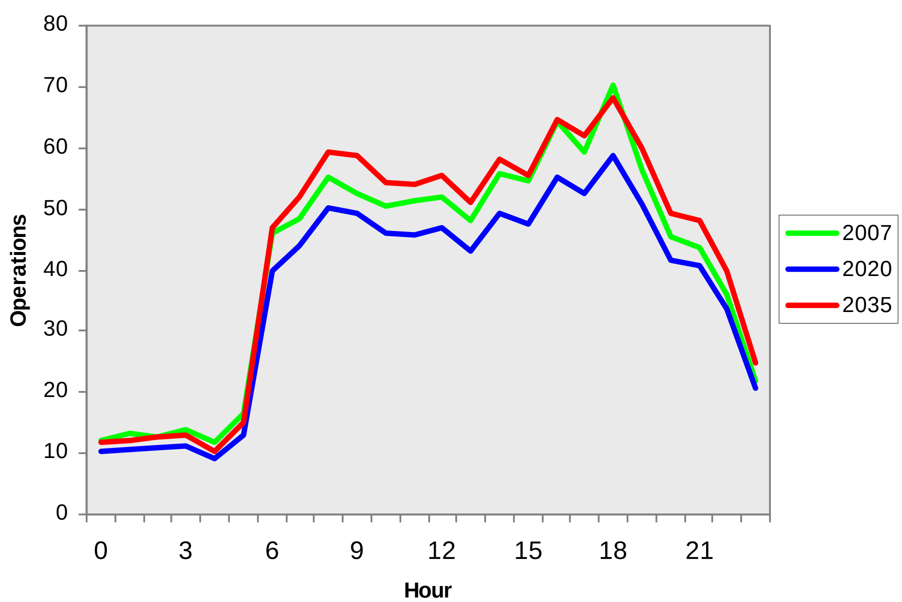
Exhibit 3-6: Monthly Variation in Average Demand at OAK, 2007



Source: Radar data.

The 2007 demand profiles for jet and non-jet operations were applied to forecast jet and non-jet operations for 2020 and 2035 to estimate future year demand profiles. Exhibit 3-7 compares the 2007 average weekday profile with those for 2020 and 2035. The 2020 profile is well below that for 2007 due to the forecast decline in GA activity. Total demand in 2035 is higher than that in 2007, but the peak is slightly lower.

Exhibit 3-7: Comparison of Average Weekday Operations per Hour, Base Year 2007 vs. Forecast 2020 and 2035



Source: Radar data.
Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009.

3.3.3 Wind Rule Assumptions

The selection of available runways for each hour modeled depends on the weather conditions for that hour. The local wind rule specifies the maximum allowable crosswind and tailwind components in knots depending on whether the runway is dry or wet. Exhibit 3-8 summarizes the wind rule assumptions for OAK.

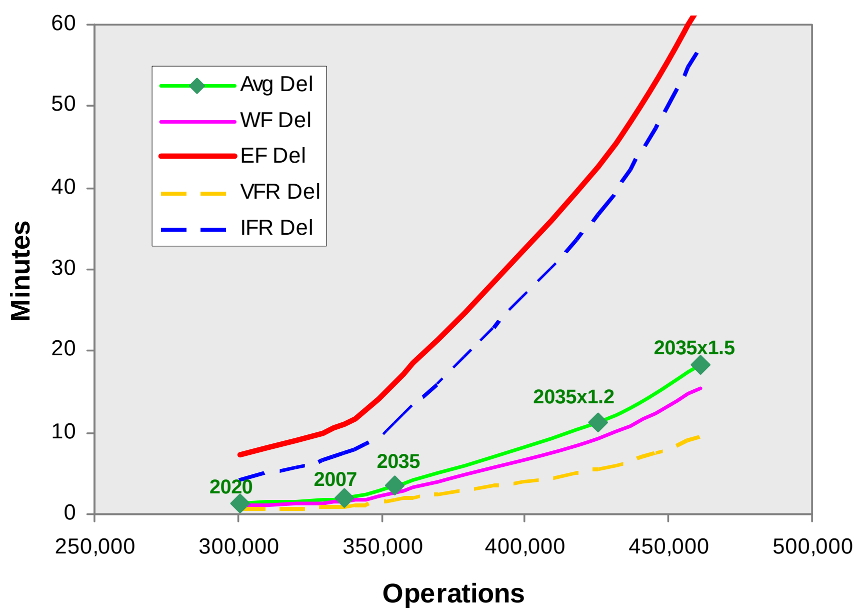
Exhibit 3-8: OAK - Maximum Allowable Crosswind and Tailwind Components, In Knots

	Dry	Wet
Crosswind	20	15
Tailwind	7	0

3.3.4 Estimated Average Aircraft Delays

DELAYSIM was run for the three analysis years: 2007, 2020 and 2035. The average aircraft delay for 2035 was only 3.5 minutes, well below the capacity threshold of 12-15 minutes, so the 2035 demand was scaled up by 20 percent, 30 percent and 50 percent to estimate when delays at OAK may become congestive. Exhibit 3-9 presents the average aircraft delay for these scenarios. In addition to the average delay shown in green, the figure also shows the average delay for East and West flow and for VFR and IFR conditions. The average delay for West Flow is only slightly lower than the overall average since this is the predominant operating condition. However, the delays for IFR and for East Flow are considerably higher than the overall average.

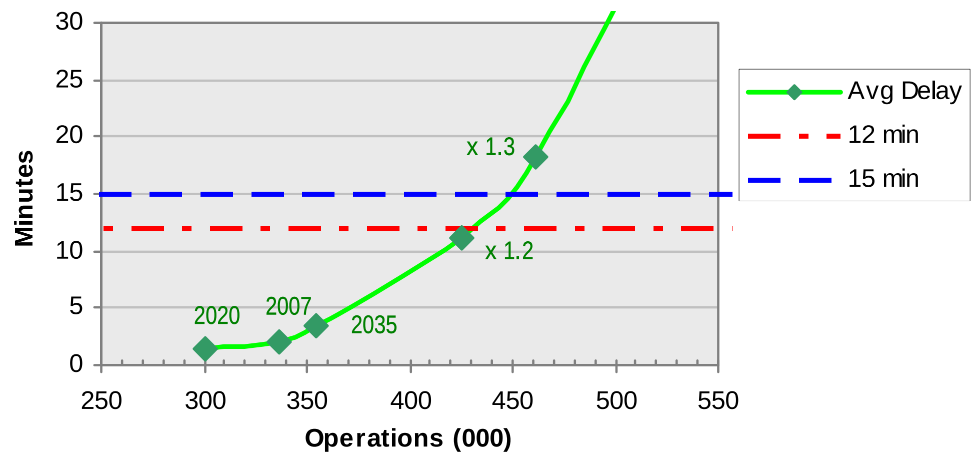
Exhibit 3-9: Base Year and Forecast Average Aircraft Delay at OAK



3.3.5 Estimated Airfield Capacity

Exhibit 3-10 presents the average aircraft delay at OAK with the delays of 12 and 15 minutes indicated. The practical annual capacity of OAK (including North Field and South Field operations) is estimated to be between 420,000 and 450,000 annual operations with the forecast fleet mix. The airport staff has suggested that a lower delay value of 8 minutes may be more appropriate for determining capacity due to the types of operations conducted by airlines using OAK. If this value is used, the airport's capacity would be approximately 400,000 annual operations. Using either criteria for delay, capacity would not be reached until after 2035.

Exhibit 3-10: Base Year and Forecast Aircraft Delays at OAK – Average Minutes of Delay vs. Annual Aircraft Operations



Airfield capacity issues at OAK stem from the single runway on the South Field which is used by nearly all commercial flights. The three runways on the North Field have restrictions on turbojet operations and are used almost exclusively by general aviation and some charter and cargo flights. When the Bay Area is operating in West Flow under VFR conditions (about 70% of the time), OAK has adequate capacity today and through 2035. According to the forecast for OAK, traffic growth is not projected to be a significant issue in the future. However, when the weather conditions deteriorate at OAK, the delays start to build up to unacceptable levels, particularly when winds force the airport to operate in East Flow (See Exhibit 3-9). East Flow occurs about 7% of the time, and when the weather drops below VFR the capacity is severely reduced. A significant issue here is the current location of the ILS Glide Slope antenna which requires departures to hold well back from the runway threshold while a landing is underway. This situation can be alleviated by moving the Glide Slope antenna or by using future GPS technology, as described in the Analysis of Advanced ATC Concepts.

3.4 Comparison with Oakland Capacity Report

The Port of Oakland commissioned an *Ultimate Airfield Capacity Study* (Jacobs study) which was completed in 2009[2]. Due to its contemporary release with this study, it was reviewed for similarity of results. However, the assumptions and methodology employed in the Jacobs study were vastly different from those utilized in the RASP Update, so direct comparisons are not possible. Nonetheless, the conclusions of both studies regarding the ultimate capacity of OAK are quite similar despite these differences. The Jacobs study predicts the ultimate OAK capacity to be 450,000 annual operations, whereas this study results in a range of 425,000 to 450,000 annual operations.

Some of the most significant differences between the two studies are summarized below:

- The Jacobs study results reflect the Master Plan improvements—including a new terminal, a proposed high-speed exit on Runway 29, taxiway improvements to expedite Runway 29 departures, and removal of the ILS hold point for Runway 11 under IFR conditions. These improvements would have a beneficial impact on airfield delays in the Jacobs analysis.
- The Jacobs simulations included taxiway and apron maneuvering as well as airspace issues. The RASP Update study only analyzes runway delays so aircraft activity beyond the runway on the ground or beyond the arrival and departure fixes in the air was not considered. The taxiway delays are relatively small, but it is difficult to assess how much the airspace delays contribute to the final results in the Jacobs study.
- Jacobs simulated four runway/weather configurations, each for 24 consecutive hours. A weighted average of the results of each was used to estimate annual delays based on composite annual weather statistics. The RASP Update study analyzed eight runway/weather configurations and used ten years of actual weather observations. IFR weather rarely lasts for 24 consecutive hours but normally occurs for a few hours between VFR or MVFR weather. The weighted average methodology used in the Jacobs study tends to significantly overstate IFR delays and to understate VFR delays.
- The Jacobs study included a nighttime airspace departure noise abatement procedure between 10 pm and 7 am. This miles-in-trail restriction over the San Francisco Bay limits OAK and SFO departures and constrains originating flights at both airports during these hours. This restriction produces an early morning spike in the delays estimated in the Jacobs study.
- Each study used different aircraft fleet mixes. The Jacobs study focused on passenger flights and used an arbitrary daily mix of 700, 750 or 800 passenger jets plus 510 GA and cargo flights for VFR conditions; they assumed a reduction in the GA demand by 236 flights during IFR conditions. The RASP Update study used the actual 2007 OAK fleet mix, and scaled it up for future years according to the forecast.

[2] Jacobs Consultancy, *Ultimate Airfield Capacity Study*, August 19, 2009.

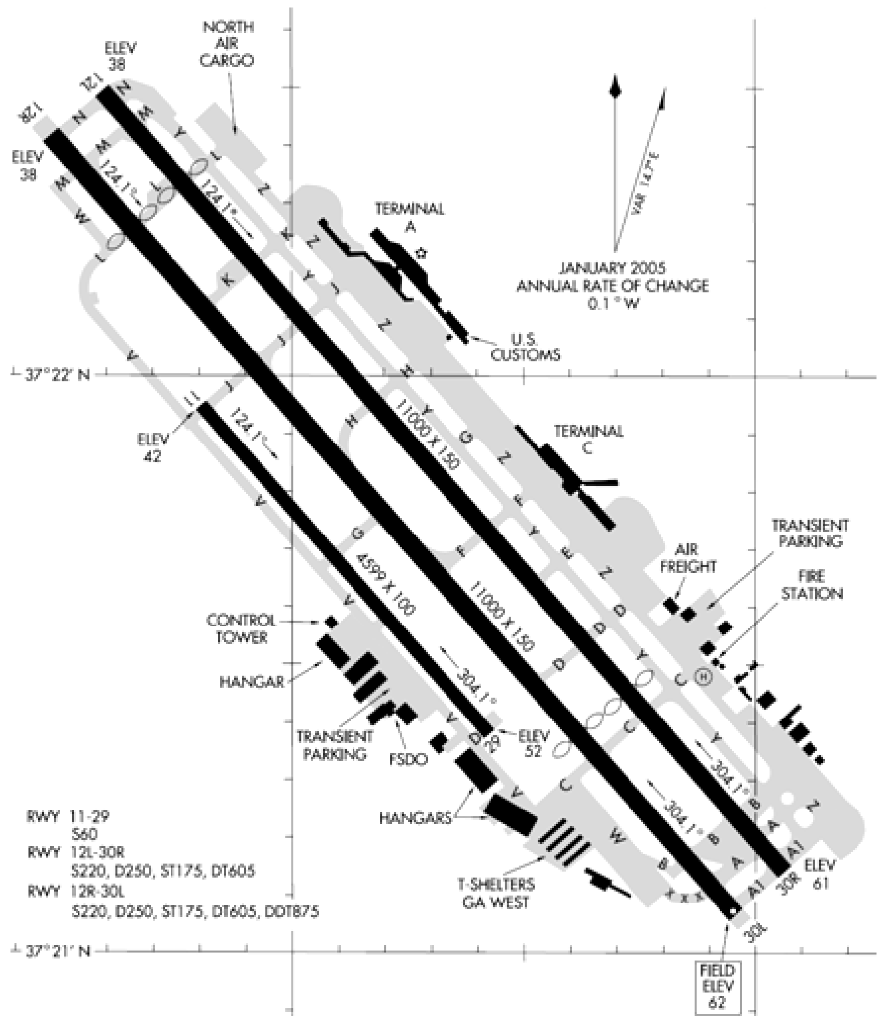
- The hourly profiles of flights for both studies are quite different. The Jacobs study produced an ADPM (average day of the peak month) profile for a hypothetical future flight schedule. This study used actual FAA radar data for 2007 to create average day profiles for weekdays, Saturdays and Sundays with monthly adjustments. The assumed number of flights per hour is a critical factor in the calculation of airfield delays.
- Although the SIMMOD model used in the Jacobs study calculates delays for all categories of traffic, the report presents the delays for passenger jets only, and ignores the GA and cargo delays. The RASP Update study calculates the average delay for all aircraft operations, including GA and cargo.
- The Jacobs study adopted an average delay of 7 minutes per passenger flight as the level of annual airfield capacity. This study used a range of 12-15 minutes of overall average delay for all flights.

4. NORMAN Y. MINETA SAN JOSE INTERNATIONAL AIRPORT (SJC)

4.1 Airport Configuration

San Jose International Airport is located at the southern end of the Bay Area and has the lowest base year and projected commercial traffic demand of the three major airports. The airport has three parallel runways: 12L-30R, 12R-30L and 11-29. Runway 11-29 on the south side of the airfield is 4,600 ft long and used primarily by general aviation. The other two runways are 11,000 ft long and serve commercial flights and most GA jets.

Exhibit 4-1: Layout of San Jose International Airport (SJC)



4.2 Runway Capacity

The FLAPS model was used to estimate the runway capacity of SJC under various operating conditions. The following sections discuss the modeling assumptions, the runway configurations modeled and the capacity results. The capacity analysis for SJC was based on the airfield layout, operating conditions and demand distribution for 2007. No further runway improvements are anticipated, but the airport is currently completing various terminal improvements on the north side of the runways, which are not depicted in Exhibit 4-1.

4.2.1 Fleet Mix Assumption

The aircraft operations and fleet mix for each analysis year are based on the actual and forecast activity presented in the *Baseline Aviation Activity Forecasts* report for SJC. Actual activity for 2007 and forecast activity for 2020 and 2035 include general aviation, air passenger and air cargo operations. For the capacity analysis, operations by aircraft type were summarized into nine aircraft classes, which distinguish operations by aircraft size and ramp area. (See Exhibit 4-2) The North ramp is where the air carrier terminals and cargo facilities are located. The South ramp is where general aviation aircraft are based, and is used mostly by GA, charter and military flights. Large jets, which have a maximum take-off weight between 41,000 and 255,000 pounds, are the dominant aircraft type and account for an increasing share of the fleet at SJC rising from 47 percent in the base year to 56 percent in 2035. Small propeller aircraft, which are projected to decline over the forecast period, account for 15 percent of activity in 2035 compared to 19 percent in 2007.

Exhibit 4-2: Summary of Base Year and Forecast Fleet Mixes for SJC

ID	Class	2007	2020	2035
SPS	Small props - South ramp	14.3%	12.1%	10.9%
SPN	Small props - North ramp	5.1%	4.3%	3.9%
SJ	Small jets	6.6%	6.2%	6.4%
LP	Large props	3.4%	2.7%	2.4%
LRJS	Large RJs & BJs - South ramp	8.9%	7.1%	8.2%
LRJN	Large RJs & BJs - North ramp	11.6%	9.3%	10.6%
LJ	Large jets	46.9%	50.1%	56.1%
5J	757s	1.8%	7.1%	0.4%
HJ	Heavy jets	1.5%	1.2%	1.1%

Notes: Small aircraft - ≤ 41,000 lbs
Large aircraft - >41,000 lbs and ≤ 255,000 lbs.
Heavy aircraft - > 255,000 lbs

Source:Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009.

4.2.2 Runway Configurations Modeled

Six configurations, consisting of combinations of runway and weather conditions, were modeled for SJC to represent operations under east and west flow for three weather conditions:

- VAPS – good VFR weather with ceilings at or above 4,500 ft and visibility at or above 5 nm.
- MVFR – marginal VFR weather below VAPS but with ceilings at or above 1,000 ft and visibility at or above 3 nm.

- IFR – IFR conditions with ceilings below 1,000 ft or visibility below 3 nm. For normal ILS operations, ceilings must be at or above 200 ft and visibility above 0.5 nm.

West Flow – VAPS

The active runways for the West Flow-VAPS configuration are Runway 29 and Runways 30L/30R. Runway 29 operates in mixed mode (both arrivals and departures). Runway 30L is used for arrivals and Runway 30R is used for departures.

Piston driven propellers from the south ramp are assigned to Runway 29 for arrival and takeoff. Piston driven propellers from the north ramp and turbo-props use Runways 29 or 30L for arrival and Runways 29 or 30R for takeoff. Small business jets are allowed to use Runways 29 or 30L for arrival but depart on Runway 30R. Large business jets and all commercial jets use Runway 30L for arrival and Runway 30R for takeoff. Reduced single-runway arrival-arrival, arrival-departure and departure-departure separations were applied to each runway to reflect the fact that the standard minimum separation standards under IFR conditions for successive operations can be reduced under good weather and good visibility conditions.

West Flow – MVFR

The runway assignments for the West Flow-MVFR configuration are the same as the runway assignments for the West Flow-VAPS configuration described above. The arrival-arrival separations for this configuration were increased to standard IFR values.

West Flow – IFR

Departure runway assignments for the West Flow-IFR configuration are the same as the runway assignments for West Flow-VAPS, but all arrivals use Runway 30L. Standard single-runway IFR separations were applied to each runway, and between Runways 29, 30L and 30R.

East Flow – VAPS

The active runways for the East Flow-VAPS configuration are Runway 11 and Runways 12L/12R. Runway 11 operates in mixed mode (both arrivals and departures). Runway 12R is used for arrivals and Runway 12L is used for departures.

Piston driven propeller aircraft from the south ramp are assigned to Runway 11 for arrival and takeoff. Piston driven propeller aircraft from the north ramp and turbo-props use Runway 11 or Runway 12R for arrival and Runway 11 or 1Runway 2L for takeoff. Small business jets are allowed to use Runway 11 or Runway 12R for arrival but depart on Runway 12L. Large business jets and all commercial jets use Runway 12R for arrival and Runway 12L for takeoff. Reduced single-runway arrival-arrival, arrival-departure and departure-departure separations were applied to each runway. Since pilots can see the other traffic around them in good weather conditions, the standard IFR separations can safely be reduced in this weather condition.

East Flow – MVFR

The runway assignments for East Flow-MVFR are the same as those for East Flow-VAPS described above. The arrival-arrival separations were increased to standard IFR values.

East Flow – IFR

For the East Flow-IFR configuration, departure runway assignments are the same as those for East Flow-VAPS, but all arrivals use Runway 12R. Standard single-runway IFR separations were applied to each runway, and between Runways 11, 12R and 12L.

4.2.3 Results

The results of the capacity analysis for SJC are shown below in Exhibit 4-3 for each of the analysis years. The values presented in the *Arrive, Depart and Saturation* columns are the maximum hourly throughput or saturation capacities for the airfield under balanced flow (i.e. equal numbers of departures and arrivals). The *Operational* column is 90 percent of the saturation capacity, based on the FAA's former method of estimating their Engineered Performance Standards for an airport. Generally, an airport's acceptance rate will lie between the theoretical Operational and Saturation capacities. For comparison, the current maximum arrival and departure acceptance rates at SJC, based on information provided by the FAA NorCal TRACON, are shown in the final two columns

Exhibit 4-3: Estimated Base Year and Forecast Runway Capacities for SJC

Year	Flow	Weather	Arrive		Depart		Capacity		NorCal	
2007	Flow	Weather	29	30L	29	30R	Saturation	Operational	Arr	Dep
2007	West	VAPS	21	31	11	40	103	93	50	40
2007	West	MVFR	11	23	7	28	69	62	40	30
2007	West	IFR		30	6	24	60	54	25	25
2007			11	12R	11	12L	Saturation	Operational	Arr	Dep
2007	East	VAPS	21	29	10	39	99	89.1	50	40
2007	East	MVFR	12	23	7	28	70	63	40	30
2007	East	IFR		30	6	24	60	54	25	25
2020			29	30L	29	30R	Saturation	Operational	Arr	Dep
2020	West	VAPS	22	32	12	42	108	97	50	40
2020	West	MVFR	10	25	6	29	70	63	40	30
2020	West	IFR		32	5	27	64	58	25	25
2020			11	12R	11	12L	Saturation	Operational	Arr	Dep
2020	East	VAPS	22	32	13	41	108	97	50	40
2020	East	MVFR	10	25	6	29	70	63	40	30
2020	East	IFR		33	5	27	65	59	25	25
2035			29	30L	29	30R	Saturation	Operational	Arr	Dep
2035	West	VAPS	22	33	11	44	110	99	50	40
2035	West	MVFR	10	26	5	31	72	65	40	30
2035	West	IFR		33	5	28	66	59	25	25
2035			11	12R	11	12L	Saturation	Operational	Arr	Dep
2035	East	VAPS	23	33	12	44	112	101	50	40
2035	East	MVFR	10	26	5	31	72	65	40	30
2035	East	IFR		33	5	28	66	59	25	25

4.3 Runway Delays

The DELAYSIM model was used to estimate runway delays at SJC. In addition to the hourly capacities presented in the previous section, DELAYSIM also requires information on hourly weather observations, an hourly aircraft demand profile and the airport's wind rule.

4.3.1 Weather Assumptions

The delay modeling was based on hourly weather data for the 10-year period, 1998 to 2007. The hourly weather observations at SJC were obtained from the National Weather Service and included the following parameters which served as inputs to DELAYSIM:

- Date and time
- Wind speed and direction

- Ceiling
- Visibility
- Precipitation

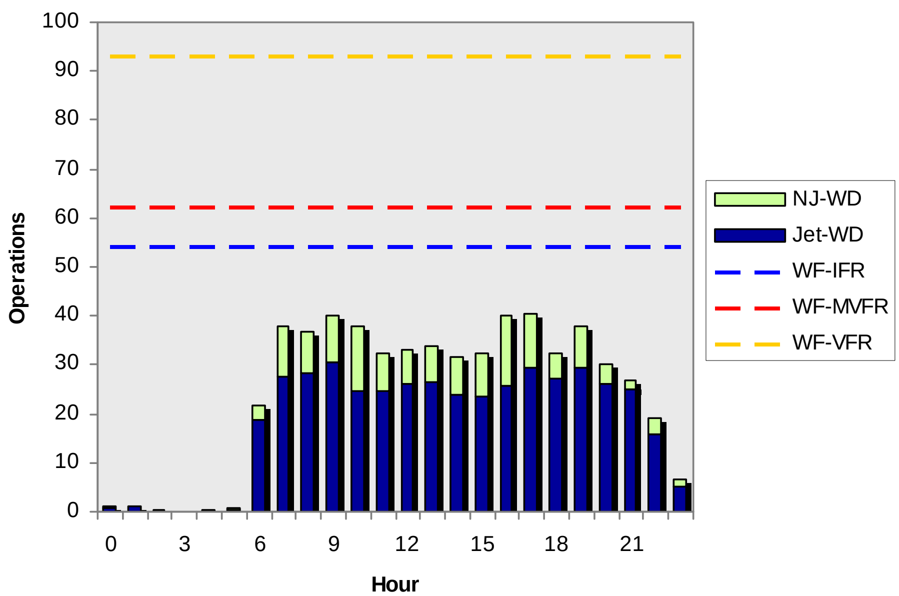
The weather data were processed to estimate missing values of some parameters, and to adjust the reported precipitation to the prior hour when it actually occurred. When more than one observation was reported in an hour, the average (wind speed and direction) or minimum (ceiling and visibility) was selected. In a few cases, where no observation was recorded, those hours were not modeled.

4.3.2 Hourly Demand Assumptions

The hourly distribution of aircraft demand is a key variable in estimating airfield delays. Radar tracking data for 2007 was used to estimate the hourly aircraft demand profiles for the base year. Separate profiles were developed for jets and non-jets, each for the average weekday, Saturday and Sunday. In addition, a monthly profile was developed to adjust the average profiles throughout the year. It should be noted that these profiles represent the total demand, including both arrivals and departures.

Exhibit 4-4 compares the jet and non-jet profiles for an average weekday in 2007. Exhibit 4-5 compares the total (jet plus non-jet) 2007 profiles for the average weekday, Saturday and Sunday. Exhibit 4-6 presents the variation in average demand by month of the year.

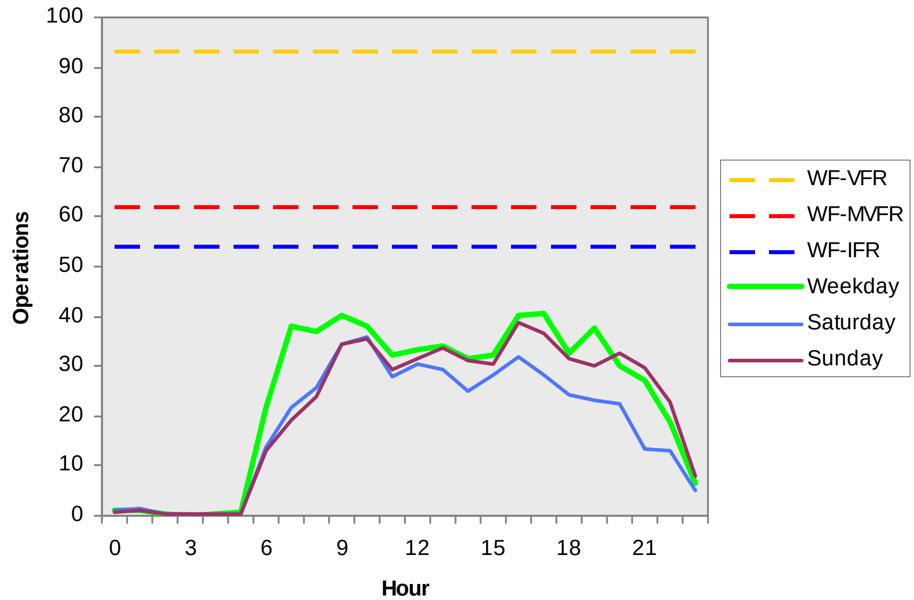
Exhibit 4-4: Jet and Non-Jet Operations per Hour at SJC, 2007 Average Weekday



Note: NJ-WD – non-jet weekday
Jet-WD – jet weekday

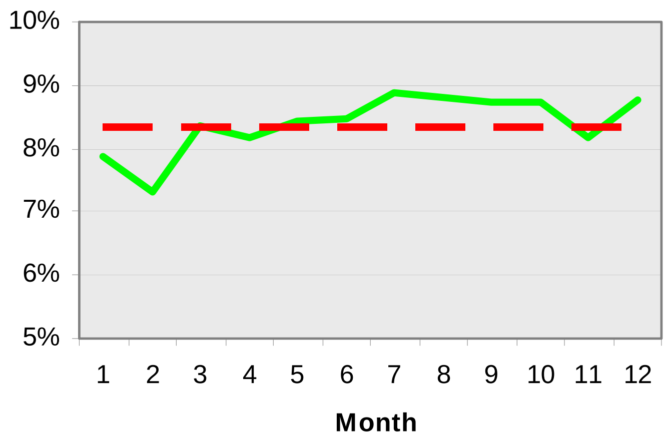
Source: Radar data.

Exhibit 4-5: Total Operations per Hour at SJC, 2007 Average Weekday, Saturday and Sunday



Source: Radar data.

Exhibit 4-6: Monthly Variation in Average Demand at SJC, 2007

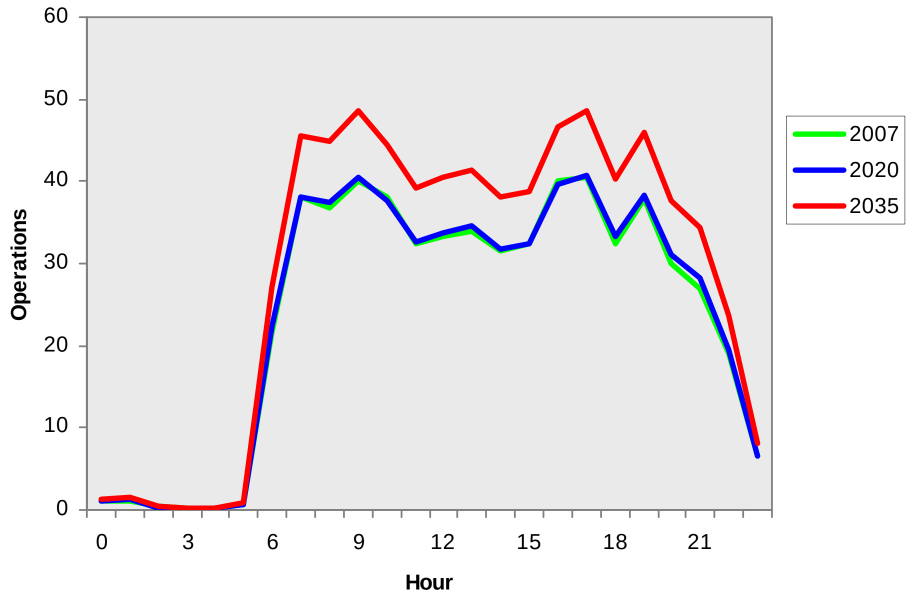


Source: Radar data.

The 2007 demand profiles for jet and non-jet aircraft operations were applied to forecast jet and non-jet operations for 2020 and 2035 to estimate future year demand profiles. Exhibit 4-7 compares the 2007 average weekday profile with those for 2020 and 2035. The 2020 profile is nearly the same as for 2007 due to the forecast decline in GA activity. Total demand in 2035 is higher than that in 2007.

Exhibit 4-7: Comparison of Average. Weekday Operations per Hour, Base Year 2007 vs. Forecast 2020 and 2035

Source: Radar data.



Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009.

4.3.3 Wind Rule Assumptions

The selection of available runways for each hour modeled depends on the weather conditions for that hour. The local wind rule specifies the maximum allowable crosswind and tailwind components in knots depending on whether the runway is dry or wet. Exhibit 4-8 summarizes the wind rule assumptions used for SJC.

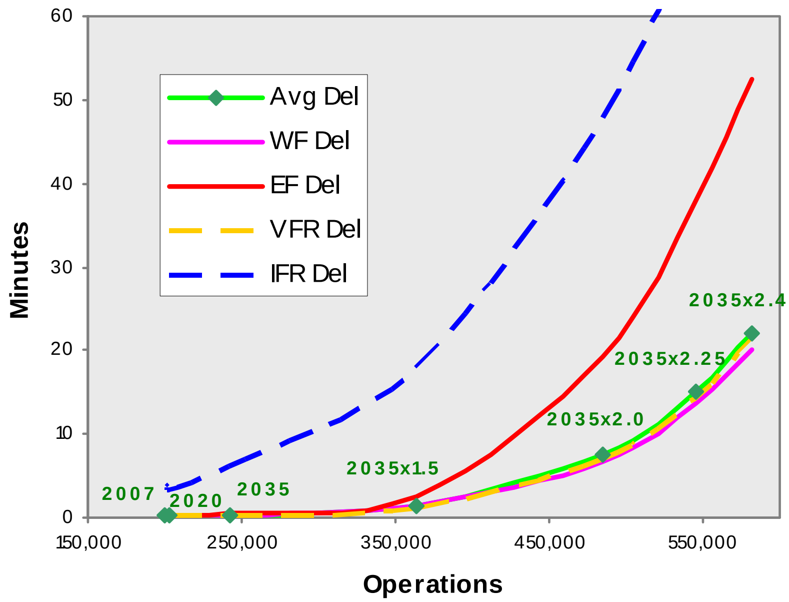
Exhibit 4-8: SJC - Maximum Allowable Crosswind and Tailwind Components, In Knots

	Dry	Wet
Crosswind	20	15
Tailwind	7	0

4.3.4 Estimated Average Aircraft Delays

DELAYSIM was run for the three analysis years: 2007, 2020 and 2035. The average aircraft delay for 2035 was less than a minute, so the 2035 demand was scaled up by 50 percent, 100 percent, 125 percent and 140 percent to estimate when delays at SJC may become congestive. Exhibit 4-9 presents the average aircraft delay for these scenarios. In addition to the average delay shown in green, the figure also shows the average delay for East and West flow and for VFR and IFR conditions. The average delay for West Flow is only slightly lower than the overall average since this is the predominant operating condition at SJC. However, the delays for IFR and for East Flow are considerably higher than the overall average.

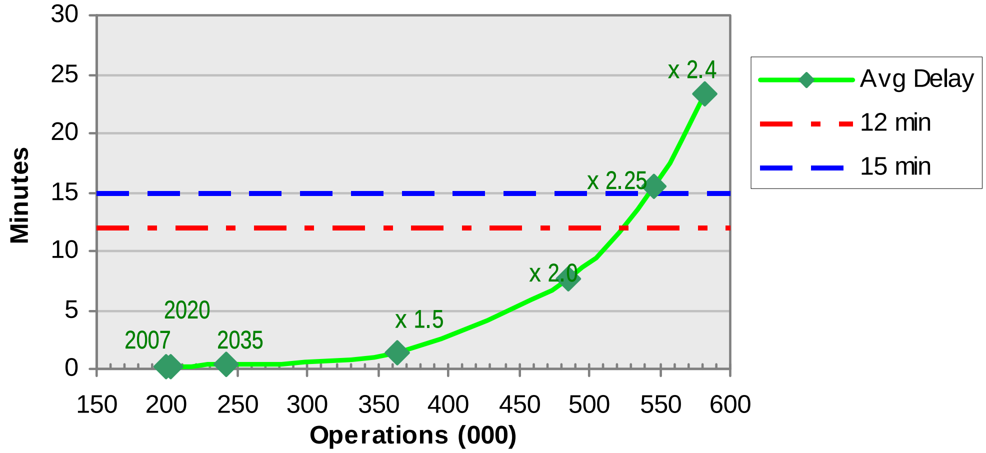
Exhibit 4-9: Base Year and Forecast Average Aircraft Delay at SJC



4.3.5 Estimated Airfield Capacity

Exhibit 4-10 depicts the average aircraft delay at SJC against the 12 and 15 minute average delay thresholds. As shown, the ultimate airfield capacity of SJC is approximately between 520,000 and 550,000 annual operations based on the forecast fleet mix. If a lower average aircraft delay of 8 minutes was used (similar to OAK), the airfield capacity would be approximately 485,000 annual operations. Using either delay value, SJC is not expected to experience runway capacity problems until well after 2035. In 2035, the average delay under all conditions is expected to be only about 1 minute per flight. Even during IFR conditions (less than 3% of the time), the average delay is projected to be less than 7 minutes in 2035 (see Exhibit 4-9). However, it should be noted that while SJC is forecast to have ample airfield capacity over the forecast period, the airport faces landside constraints that are likely to limit the airfield from reaching its full capacity.

Exhibit 4-10: Base Year and Forecast Aircraft Delays at SJC – Average Minutes of Delay vs. Annual Aircraft Operations

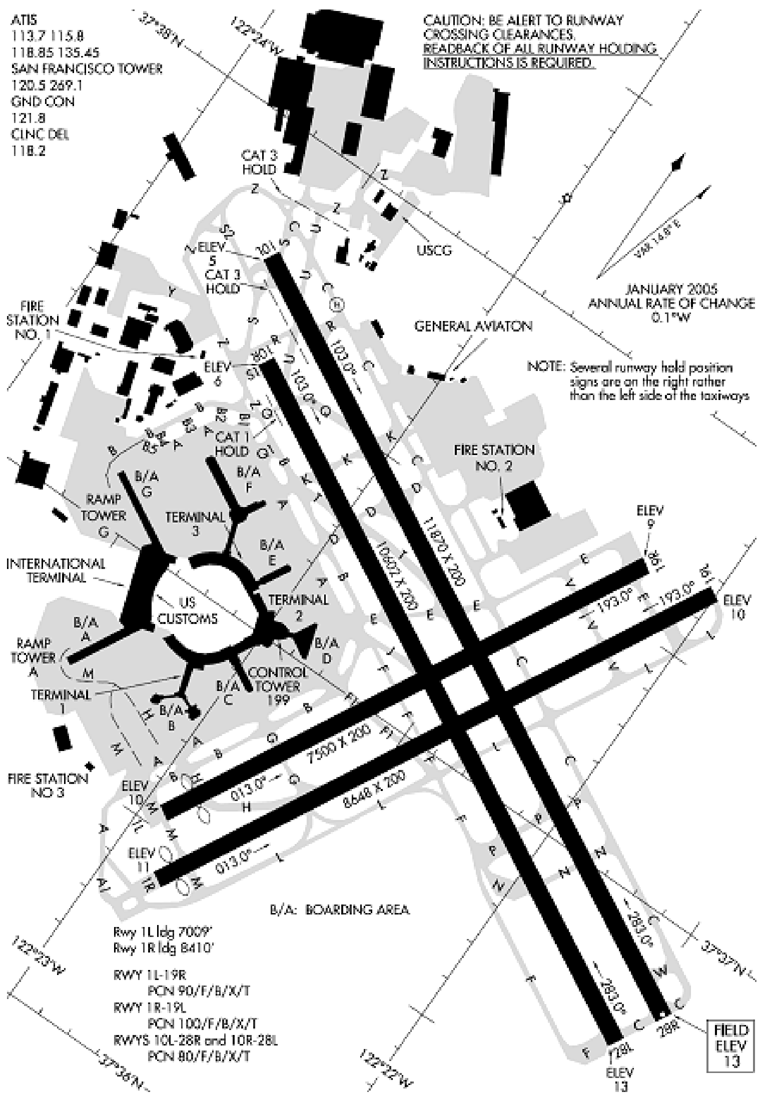


5. SAN FRANCISCO INTERNATIONAL AIRPORT (SFO)

5.1 Airport Configuration

San Francisco International Airport is the busiest commercial airport in the Bay Area. The airfield layout consists of two pairs of closely-spaced parallel runways: 10L-28L, 10R-28L, 01L-19R and 01R-19L. When weather conditions permit, the parallel runways are used together during periods of high demand to permit simultaneous pairs of arrivals and/or departures.

Exhibit 5-1: Layout of San Francisco International Airport



5.2 Runway Capacity

The FLAPS model was used to estimate the runway capacity of SFO under various operating conditions. The following sections discuss the modeling assumptions, runway configurations modeled and the capacity results. The capacity analysis of SFO was based on the existing airfield layout, operating conditions and demand distribution for 2007. Although San Francisco International Airport has studied additional potential runway configurations in the past, these are not considered in this study.

5.2.1 Fleet Mix Assumptions

Aircraft operations and fleet mix assumptions for the analysis years are based on the actual and forecast activity data presented in the *Baseline Aviation Activity Forecasts* report for SFO. Actual aircraft activity for 2007 and forecast aircraft activity for 2020 and 2035 include general aviation, air passenger and air cargo operations. For the capacity analysis SFO operations by aircraft type were summarized into nine aircraft classes, which distinguish operations by aircraft size and by runway length requirements for large, heavy and Boeing 757 jets. Large and heavy jets are forecast to account for an increasing share of SFO's aircraft operations. The large jet share increases from 55 percent in 2007 to 74 percent in 2035. Similarly, heavy jets grow from 15 percent of the SFO fleet in the base year to nearly 20 percent in 2035. (See Exhibit 5-2)

Exhibit 5-2: Summary of Base Year and Forecast Fleet Mixes for SFO

ID	Class	Runway Length Requirement	2007	2020	2035
SP	Small props		1.7%	0.9%	0.8%
SJ	Small jets		3.0%	2.2%	2.0%
LP	Large props		13.4%	5.5%	3.3%
LJS	Large jets	takeoff < 8600 ft	50.9%	61.4%	68.7%
LJL	Large jets	takeoff > 8600 ft	4.0%	4.8%	5.4%
5JS	757s	takeoff < 8600 ft	10.9%	7.9%	0.0%
5JL	757s	takeoff > 8600 ft	0.6%	0.5%	0.0%
HJS	Heavy jets	takeoff < 8600 ft	0.9%	1.0%	1.2%
HJL	Heavy jets	takeoff > 8600 ft	14.5%	15.7%	18.6%

Notes: Small aircraft - ≤ 41,000 lbs
Large aircraft - >41,000 lbs and ≤ 255,000 lbs.
Heavy aircraft - > 255,000 lbs

Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009.

5.2.2 Configurations

Fourteen configurations, consisting of runway and weather condition combinations, were modeled for SFO to represent operations under east and west flow for three primary weather conditions:

- VAPS – good VFR weather with ceilings at or above 4,500 ft and visibility at or above 5 nm.
- MVFR – marginal VFR weather below VAPS but with ceilings at or above 1,000 ft and visibility at or above 3 nm.

- IFR – Instrument Flight Rule conditions with ceilings below 1,000 ft or visibility below 3 nm. For normal ILS operations, ceilings must be at or above 200 ft and visibility above 0.5 nm. For west flow, two additional IFR configurations were included: ILS Cat II (with a minimum ceiling of 100 ft and visibility of 0.33 nm) and ILS Cat III (with a minimum ceiling of zero ft and zero visibility).

West Flow – VAPS

The preferred configuration for SFO is to use Runways 28L/R for simultaneous pairs of arrivals, which are spaced side by side (commonly called wingtip operations). Most departures also are paired side-by-side on Runways 01L/R. Heavy and long-haul departures which need more than 8,600 feet of runway for takeoff use either Runway 28L or Runway 28R for departure. Standard minimum IFR separations were reduced for single-runway arrival-arrival, arrival-departure and departure-departure separations. Wake-vortex separations were applied between arrivals on Runways 28L/R and departures on Runways 01L/R.

West Flow – MVFR

The following configurations were analyzed for MVFR conditions.

Expanded Visuals – For this configuration, all arrivals are assigned to either Runway 28L or Runway 28R, but staggered separations are required on the two approaches. Departures which need less than 8,600 feet depart on Runway 01L or Runway 01R, and can be launched in pairs if crosswinds permit. Departures requiring more than 8,600 feet use Runways 28L/R. If crosswinds do not allow use of Runways 01L/R, all departures use Runways 28L/R between arrivals. The minimum weather conditions are a ceiling of 2,400 ft and visibility of 5 nm.

Simultaneous Offset Instrument Approaches (SOIA) – In this configuration, paired arrivals are sequenced on the ILS to Runway 28L and the Localizer Type Directional Aid (LDA) to Runway 28R. Paired departures requiring less than 8,600 feet for takeoff are launched from Runways 01L/R if wind permits; otherwise all departures use Runways 28L/R between arrivals. All departures requiring more than 8,600 feet use Runways 28L/R. The minimum weather conditions are currently a ceiling of 2,100 ft and visibility of 4 nm.

The arrival-arrival separations were increased to standard IFR values.

West Flow – IFR

Whenever weather conditions are lower than the SOIA requirements, SFO operates with standard ILS arrivals on runway 28R. If crosswinds allow, flights can depart on Runways 01L/R individually or in pairs. Otherwise, all departures take place on Runways 28L/R. Standard single-runway IFR separations were applied to each runway, and between Runways 01L/R and 28L/R. The ILS Cat II and ILS Cat III configurations were adapted from another study (for Boston Logan International Airport) which assumed reductions in the fleet mix and increases in arrival-arrival separations.

East Flow – VAPS

For the East Flow – VAPS configuration, all arriving flights occur on Runways 19L/R with staggered separations; departures use Runways 10L/R with wingtip separations. Standard IFR minimum separations were reduced for single-runway arrival-arrival, arrival-departure and departure-departure separations.

East Flow – MVFR

For the East Flow – MVFR configuration, all arrivals are to Runways 19L/R with staggered separations; departures use 10L/R with wingtip separations unless crosswinds prohibit, otherwise departures are assigned to Runways 19L/R. The arrival-arrival separations were increased to standard IFR values.

East Flow – IFR

In the East Flow – IFR configuration, all arrivals use Runway 19L. Departures are assigned to Runways 10L/R unless crosswinds are too strong. With strong crosswinds departures are interspersed with arrivals on Runways 19L/R. Standard IFR separations were imposed.

5.2.3 Results

The results of the capacity analysis are shown below in Exhibit 5-3 for each of the analysis years. The values presented in the *Arrive*, *Depart* and *Saturation* columns are the maximum hourly throughput or saturation capacities for the airfield under balanced flow (i.e., equal numbers of departures and arrivals). The *Operational* column is 90 percent of the saturation capacity, based on the FAA's former method of estimating their Engineered Performance Standards for an airport. Generally, an airport's acceptance rate will lie between the theoretical Operational and Saturation capacities. For comparison, the current maximum arrival and departure acceptance rates at SFO, based on information provided by FAA's NorCal TRACON, are shown in the final two columns

Exhibit 5-3: Estimated Base Year and Forecast Runway Capacities for SFO

			Arrive		Depart				Capacity		NorCal	
	Flow	Weather	28L	28R	01L	01R	28L	28R	Saturation	Operational	Arr	Dep
2007	West	VAPS	27	27	15	25	7	6	107	96	60	50
	West	SOIA	21	21	15	19	4	4	84	76	36	42
	West	SOIA	21	21			23	18	83	75	36	42
	West	MVFR	25	23	13	23	7	6	97	87	45	48
	West	MVFR	19	26			30	16	91	82	45	40
	West	IFR		31	10	15	6		62	56	30	42
	West	IFR		31			24	7	62	56	30	38
			19L	19R	10L	10R	19L	19R	Saturation	Operational	Arr	Dep
	East	VAPS	24	19	25	18			86	77	40	40
	East	MVFR	15	16	19	12			62	56	27	40
	East	MVFR	20	10			12	17	59	53	25	35
	East	IFR	30		26	4			60	54	27	40
	East	IFR	29				3	25	57	51	25	33
2020			28L	28R	01L	01R	28L	28R	Saturation	Operational	Arr	Dep
	West	VAPS	28	27	15	25	9	6	110	99	60	50
	West	SOIA	22	22	15	19	5	5	88	79	36	42
	West	SOIA	22	22			24	20	88	79	36	42
	West	MVFR	25	25	12	22	8	8	100	90	45	48
	West	MVFR	18	26			29	15	88	79	45	40
	West	IFR		34	9	17	8		68	61	30	42
	West	IFR		34			29	5	68	61	30	38
			19L	19R	10L	10R	19L	19R	Saturation	Operational	Arr	Dep
	East	VAPS	23	20	27	16			86	77	40	40
	East	MVFR	16	15	21	10			62	56	27	40
	East	MVFR	19	11			14	16.7	61	55	25	35
	East	IFR	29		26	4			59	53	27	40
	East	IFR	29				4	25.1	58	52	25	33
2035			28L	28R	01L	01R	28L	28R	Saturation	Operational	Arr	Dep
	West	VAPS	28	28	14	25	10	6	111	100	60	50
	West	SOIA	23	22	15	19	6	6	91	82	36	42
	West	SOIA	23	22			24	21	90	81	36	42
	West	MVFR	26	26	11	22	10	9	104	94	45	48
	West	MVFR	19	27			30	16	92	83	45	40
	West	IFR		34	8	16	10		68	61	30	42
	West	IFR		34			28	6	68	61	30	38
			19L	19R	10L	10R	19L	19R	Saturation	Operational	Arr	Dep
	East	VAPS	25	18	31	13			87	78	40	40
	East	MVFR	15	16	19	12			62	56	27	40
	East	MVFR	19	11			14	15.9	60	54	25	35
	East	IFR	29		25	4			58	52	27	40
	East	IFR	29				4	26	59	53	25	33

5.3 Runway Delays

Runway delays were estimated using the DELAYSIM model as described in Section 2. In addition to the hourly capacity inputs presented above, DELAYSIM also requires information on hourly weather observations, an hourly aircraft demand profile and the airport's wind rule, which are described below.

5.3.1 Weather Assumptions

Ten years of hourly weather observations at SFO for the period 1998 through 2007 were used in the DELAYSIM model.

The weather data were obtained from the National Weather Service and included the following parameters as inputs to the delay model:

- Date and time
- Wind speed and direction
- Ceiling
- Visibility
- Precipitation

The weather data were processed to estimate missing values of some parameters, and to adjust the reported precipitation to the prior hour when it actually occurred. When more than one observation was reported in an hour, the average (wind speed and direction) or minimum (ceiling and visibility) was selected. In a few cases, where no observation was recorded, those hours were not modeled.

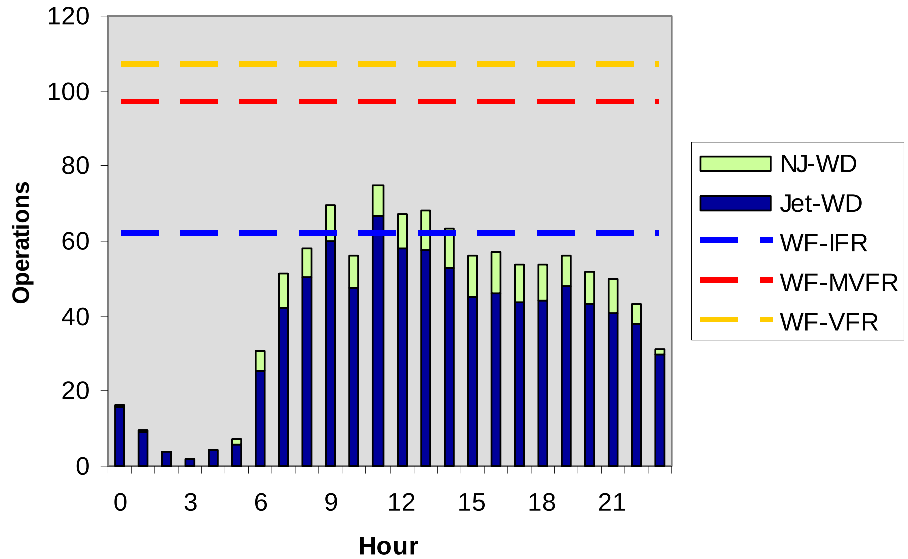
The resulting file, with date and time in GMT, was then input into the DELAYSIM model.

5.3.2 Hourly Demand Assumptions

A key variable in estimating airfield delays is the number and type of aircraft that need to arrive or depart during each hour. Radar tracking data for 2007 was used to estimate the hourly aircraft demand profiles for the base year. Separate profiles were developed for jets and non-jets, each for the average weekday, Saturday and Sunday. In addition, a monthly profile was developed to adjust the average profiles throughout the year. It should be noted that these profiles represent the total demand, including both arrivals and departures.

Exhibit 5-4 compares the jet and non-jet profiles for an average weekday in 2007. Exhibit 5-5 compares the total (jet plus non-jet) 2007 profiles for the average weekday, Saturday and Sunday and compares these to the airport’s typical capacity. Exhibit 5-6 presents the variation in average demand by month of the year.

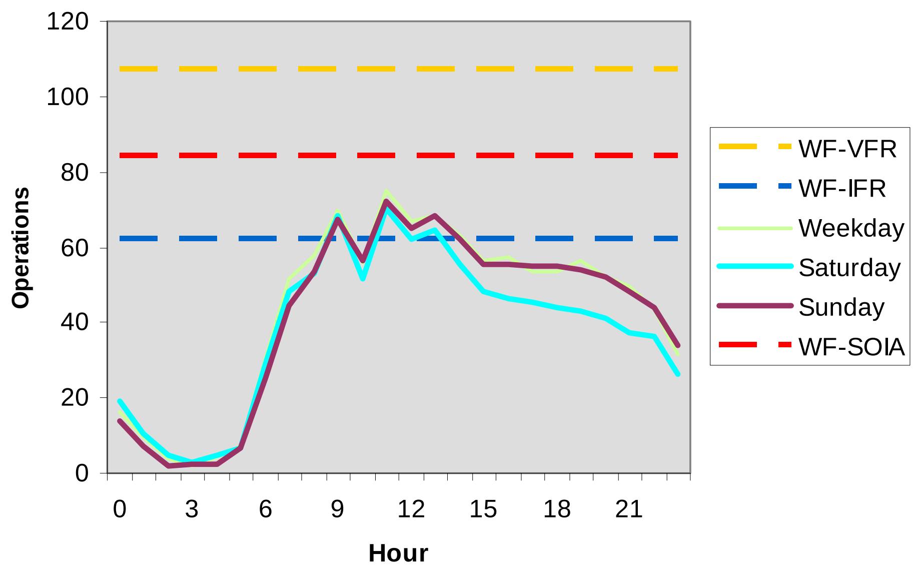
Exhibit 5-4: Jet and Non-Jet Operations per Hour at SFO, 2007 Average Weekday



Note: NJ-WD – non-jet weekday
Jet-WD – jet weekday

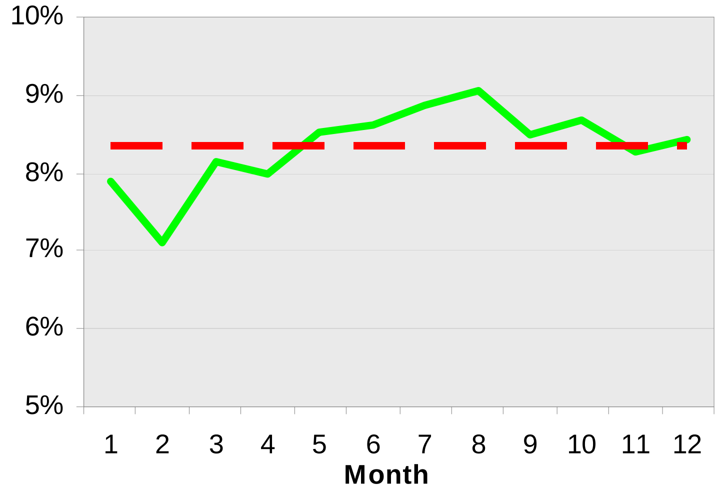
Source: Radar data.

Exhibit 5-5: Total Operations per Hour at SFO, 2007 Average Weekday, Saturday and Sunday



Source: Radar data.

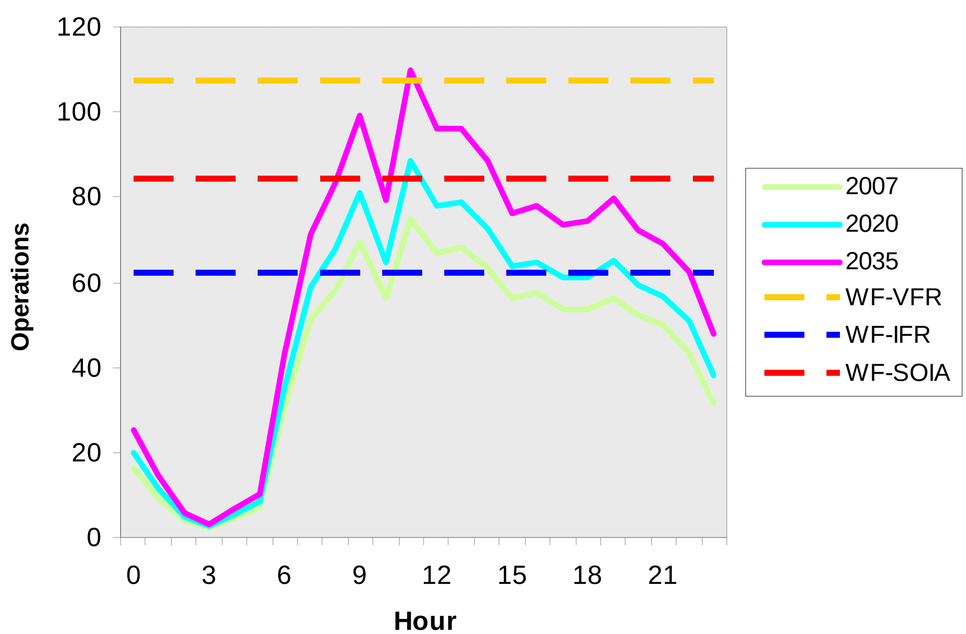
Exhibit 5-6: Monthly Variation in Average Demand at SFO, 2007



Source: Radar data.

The jet and non-jet demand profiles for 2007 were applied to the forecasts of jet and non-jet operations for 2020 and 2035 to estimate future year demand profiles. Exhibit 5-7 compares the 2007 average weekday profile with those for 2020 and 2035.

Exhibit 5-7: Comparison of Average Weekday Operations per Hour, Base Year 2007 vs. Forecast 2020 and 2035



Note: Capacities are for 2035.

Source: Radar data.

5.3.3 Wind Rule Assumptions

The selection of available runways each hour depends on the weather conditions. The local wind rule, summarized in Exhibit 5-8, specifies the maximum allowable crosswind and tailwind components in knots depending on whether the runway is dry or wet.

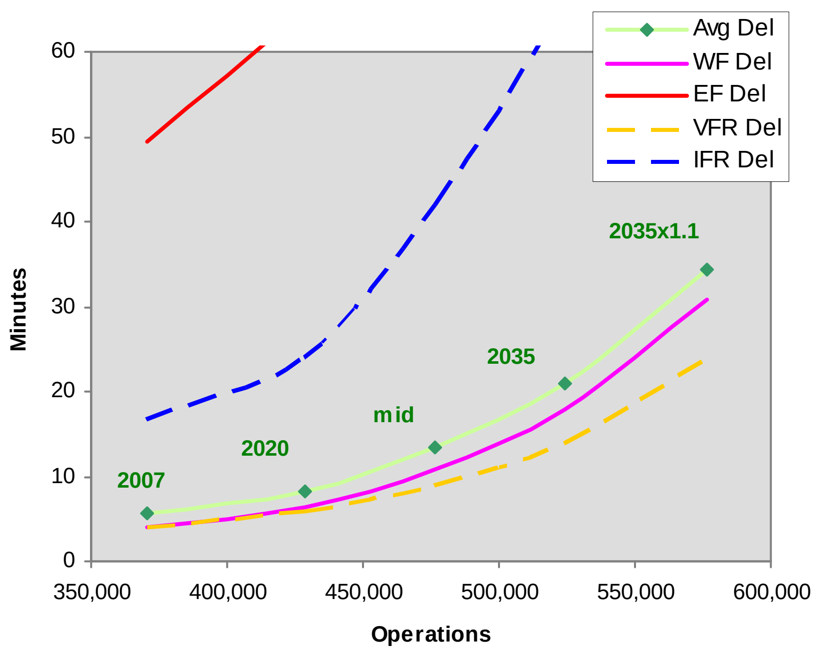
Exhibit 5-8: SFO - Maximum Allowable Crosswind and Tailwind Components, In Knots

	Dry	Wet
Crosswind	20	15
Tailwind	7	0

5.3.4 Estimated Average Aircraft Delays

DELAYSIM was run for the three analysis years: 2007, 2020 and 2035. Exhibit 5-9 shows the average aircraft delay in green, and also shows the average delay for East and West flow and for VFR and IFR conditions. Average delays at SFO is projected to increase from 5.7 minutes in the base year to 8.4 minutes in 2020 and 21.0 minutes in 2035.The average delay for West Flow is only slightly lower than the overall average since this is the predominant operating condition. However, the delays for IFR and for East Flow are considerably higher than the overall average.

Exhibit 5-9: Base Year and Forecast Average Aircraft Delay at SFO

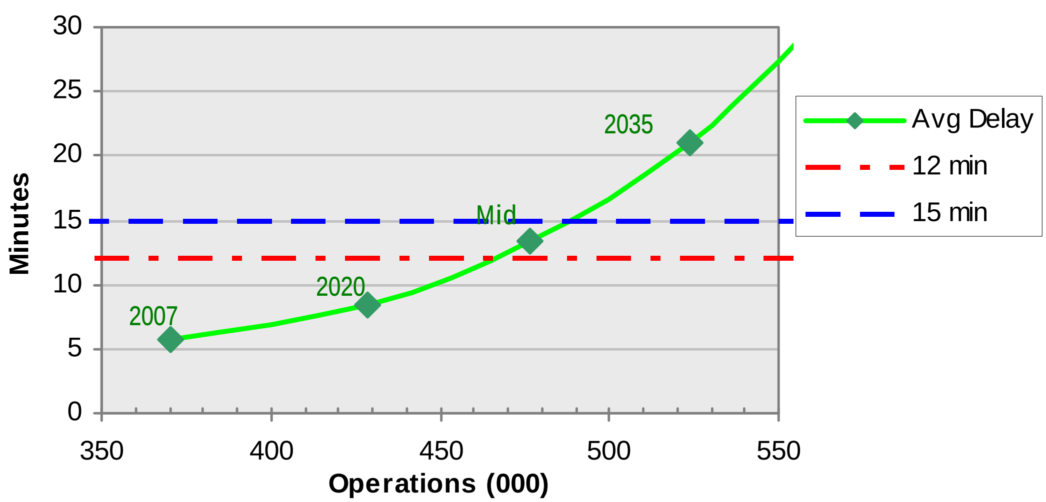


5.3.5 Estimated Airfield Capacity

Exhibit 5-10 presents the average aircraft delay at SFO against the average delay thresholds of 12 and 15 minutes. The ultimate capacity of SFO is approximately 460,000 to 485,000 annual operations, based on the forecast fleet mix and the 12 to 15 minute delay threshold. Using this delay threshold, SFO is projected to exceed its airfield capacity and reach unacceptable levels of congestion some time after 2020 and before 2035. SFO officials believe a lower threshold may be appropriate for assessing the airport's capacity since arrival delays are significantly greater than departure delays.

The major airfield capacity issues at SFO are the variability of weather conditions and the forecast growth of traffic through 2035. When the airport is operating in West Flow under good VFR conditions (56% of the time), the ability to conduct simultaneous paired arrivals keeps the average delay under 2 minutes through 2020. But with the forecast traffic growth, this will increase to over 10 minutes by 2035. The problems occur when stratus clouds over the Bay or unfavorable winds preclude the use of paired approaches. Even with the use of paired arrivals under Simultaneous Offset Instrument Approaches (SOIA), runway capacity is reduced by about 20% and the average delays approach unacceptable levels today. When weather conditions are IFR (about 16% of the time) or when winds require the use of Southeast Flow (between 3% and 4% of the time), the delays escalate enormously (see exhibit 5-9). The average delay for all conditions is projected to be about 21 minutes in 2035, but Advanced ATC Concepts hold promise to reduce this significantly.

Exhibit 5-10: Base Year and Forecast Aircraft Delays at SFO – Average Minutes of Delay vs. Annual Aircraft Operations



APPENDIX
BASELINE CAPACITY AND DELAY REPORT

Base Case Forecast Aircraft Operations at Primary Bay Area Airports

Category	Oakland 2007	Oakland 2020	Oakland 2035	San Francisco 2007	San Francisco 2020	San Francisco 2035	San Jose 2007	San Jose 2020	San Jose 2035
Air Carrier Passenger	155,900	161,100	192,600	326,200	384,600	461,200	127,800	129,500	153,000
All-Cargo	32,200	34,300	40,500	9,800	12,000	19,000	3,000	3,200	3,700
Subtotal Air Carrier	188,100	195,400	233,100	336,000	396,600	480,200	130,800	132,700	156,700
GA - Jets	18,600	23,300	33,200	27,800	27,600	39,300	28,600	31,100	44,300
GA - Nonjets	48,900	35,900	38,700	6,400	4,300	4,500	24,600	23,100	24,900
Total GA (Itinerant)	67,500	59,200	71,900	34,200	31,900	43,800	53,200	54,200	69,200
Subtotal Above	**255,600**	**254,600**	**305,000**	**370,200**	**428,500**	**524,000**	**184,000**	**186,900**	**225,900**
Military (total)	400	400	400	2,700	2,700	2,700	100	100	100
GA - Local Ops	81,300	46,000	49,600	100	-	-	15,700	15,500	16,700
Subtotal Local & Military	81,700	46,400	50,000	2,800	2,700	2,700	15,800	15,600	16,800
Total All Operations	**337,300**	**301,000**	**355,000**	**373,000**	**431,200**	**526,700**	**199,800**	**202,500**	**242,700**

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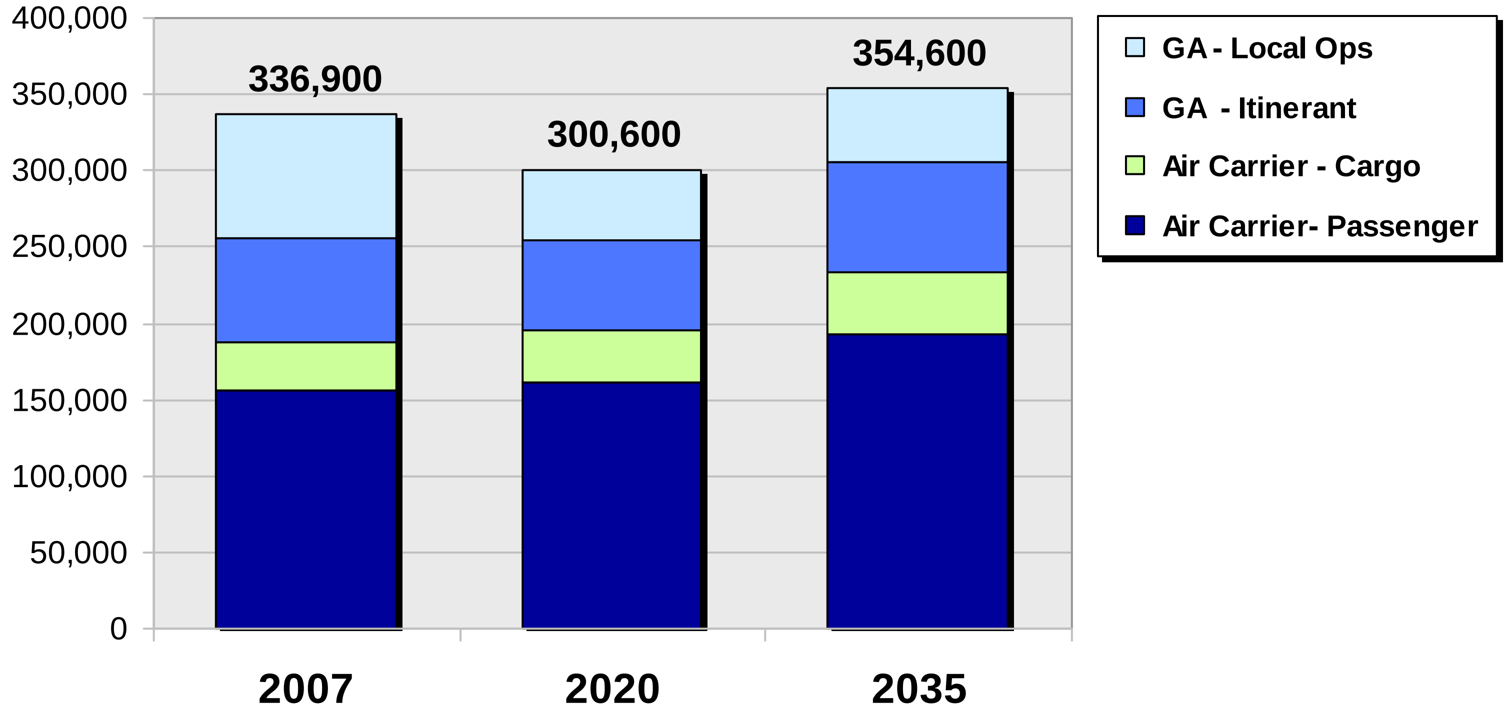
OAK's Runway Demand is Forecast to Decline from 2007 to 2020, then Resume Growth, Increasing to 355,000 Operations in 2035

Annual Aircraft Operations

Baseline 2007 and Base Case Forecast 2020 and 2035



Note: Includes runway demand for both the North and South Fields. Excludes military operations.

Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009

Large and Heavy Weight Aircraft are Forecast to Account for an Increasing Share of OAK's Aircraft Demand

Annual Operations by Aircraft Weight Class and Type

Baseline 2007 and Base Case Forecast 2020 and 2035

Weight Class	Type	Percent of Annual Operations 2007	2020	2035
Small	Jet	3.0%	3.9%	4.2%
	Non-Jet	40.1%	28.9%	26.6%
	Subtotal	**43.1%**	**32.8%**	**30.8%**
Large	Turboprop	1.9%	2.4%	2.3%
	Jet	43.1%	49.3%	51.5%
	Regional Jet	6.0%	7.0%	8.3%
	Subtotal	**51.0%**	**58.7%**	**62.0%**
Boeing 757	**Jet**	**0.8%**	**1.7%**	**0.3%**
Heavy	**Jet**	**5.1%**	**6.9%**	**6.9%**
Total		100.0%	100.0%	100.0%

Notes: Small = <44,000 lbs; Large = >44,000 lbs and < 300,000 lbs; Heavy = > 300,000 lbs

Excludes military operations.

Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009

OAK's Maximum Capacity Configuration Can Accommodate Over 70% of Operations

Modeled Capacities of Runway Configurations

Baseline 2007 and Base Case Forecast 2020 and 2035

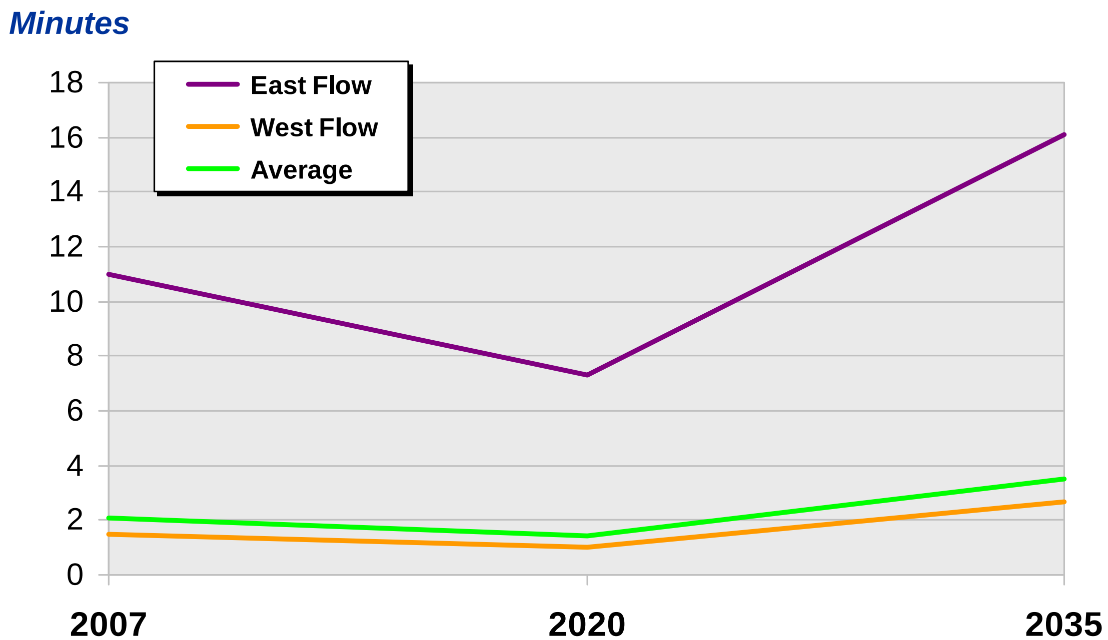
				Runways				Capacity (ops/hr)		
Percent of 2007 Ops	Configuration ID	Flow	Weather	Jet Landings	Non-Jet Landings	Jet Take-offs	Non-jet Take-offs	2007	2020	2035
72.0%	D-01-VAPS-01	West	VFR	27L 27R 29	27L 27R 29	29	27L 27R 29	105	88	85
16.2%	D-01-IFR-01	West	IFR	27R 29	27R 29	29	27L	55	54	54
5.6%	D-01-MVFR-03	West	MVFR	27L 27R 29	27L 27R 29	29	27L 27R 29	67	61	59
2.4%	D-02-VAPS-03	East	VFR	11	09L 09R 11	09L 09R 11	09L 09R 11	76	71	70
2.0%	D-02-MVFR-02	East	MVFR	11	11	09L 09R 11	09L 09R 11	56	52	51
1.4%	D-02-IFR-03	East	IFR	11	11	09R 11	09R 11	44	43	45
0.2%	D-01-IFR-04	West	IFR	29	29	29	29	39	39	39
0.1%	D-01-IFR-03	West	IFR	29	29	29	29	44	44	44

Average Delay at OAK is Estimated at Less than 4 minutes Over the Forecast Period, but East Flow Delays Reach 16 Minutes in 2035

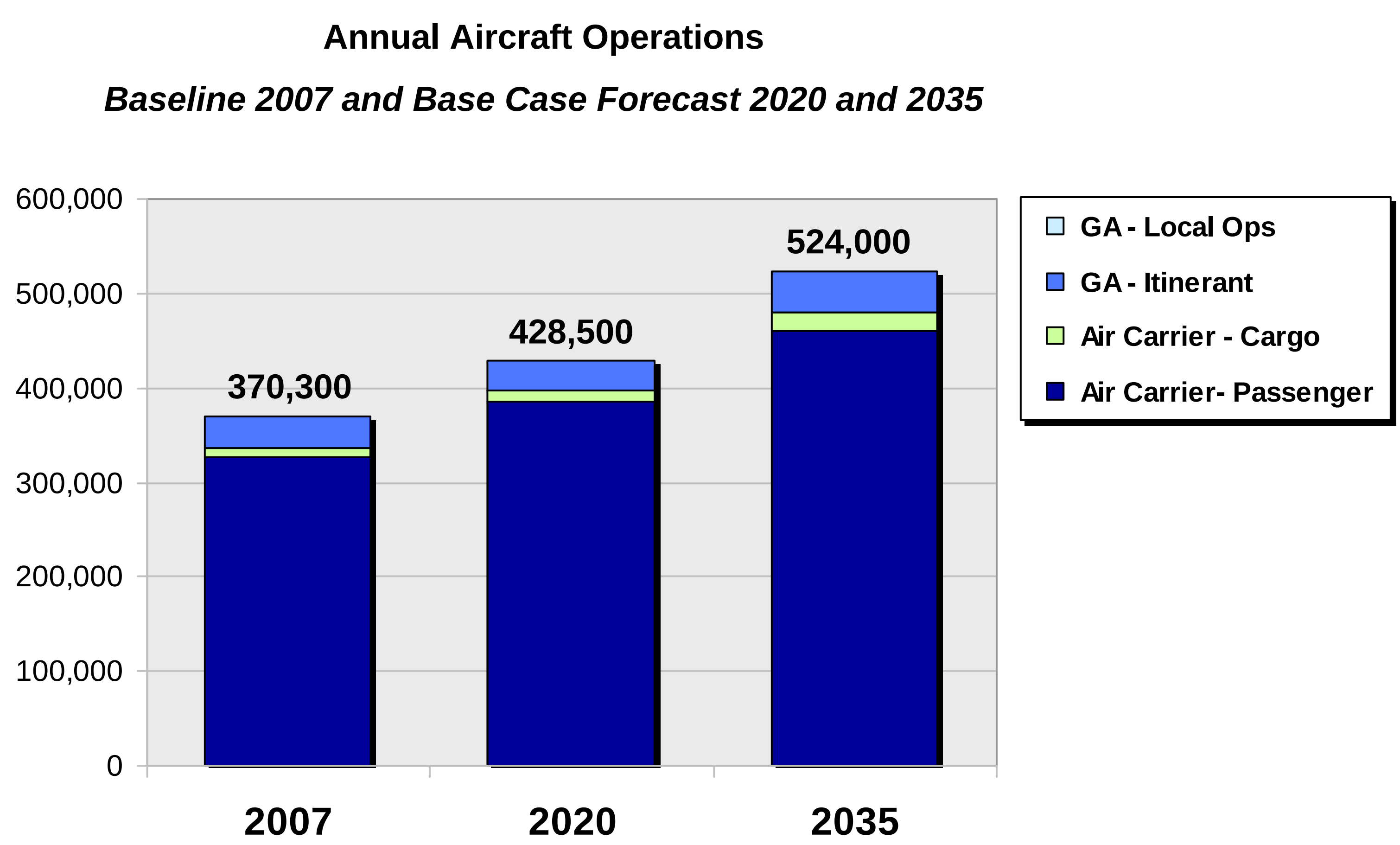
- **OAK operates to the West 93% of the time**
- **East flow capacity under IFR is reduced due to the displaced ILS hold point for departures on Runway 11**
- **GPS approaches in East flow exist to the North Field but conflict with the ILS to the South Field**

Average Minutes of Delays by Major Operating Conditions

Baseline 2007 and Forecast 2020 and 2035



Runway Demand at SFO is Projected to Increase by 42% Over the Forecast Period



Note: Excludes military operations.

Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009

The Future Fleet Mix at SFO Reflects Its Role as an International Gateway, with Large and Heavy Jets Accounting for an Increasing Share of Aircraft Operations

Annual Operations by Aircraft Weight Class and Type

Baseline 2007 and Base Case Forecast 2020 and 2035

Weight Class	Type	Percent of Annual Operations		
		2007	2020	2035
Small	Jet	3.0%	2.3%	2.2%
	Non-Jet	1.7%	1.0%	0.8%
	Subtotal	**4.8%**	**3.2%**	**3.1%**
Large	Turboprop	13.4%	7.9%	3.8%
	Jet	38.2%	46.3%	57.5%
	Regional Jet	16.7%	14.3%	13.2%
	Subtotal	**68.2%**	**68.4%**	**74.5%**
Boeing 757	**Jet**	**11.6%**	**9.4%**	**0.0%**
Heavy	**Jet**	**15.4%**	**18.9%**	**22.4%**
Total		100.0%	100.0%	100.0%

Notes: Small = <44,000 lbs; Large = >44,000 lbs and < 300,000 lbs; Heavy = > 300,000 lbs

Excludes military operations.

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Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009

When Operating in West Flow VFR Conditions, SFO Can Accommodate up to 100 Operations per Hour

Modeled Capacities of Runway Configurations

Baseline 2007 and Base Case Forecast 2020 and 2035

				Runways				Capacity (ops/hr)		
Percent of 2007 Ops	Configuration ID	Flow	Weather	Jet Landings	Non-Jet Landings	Jet Take-offs	Non-jet Take-offs	2007	2020	2035
58.1%	D-01-VAPS-01	West	VFR	28L 28R	28L 28R	01L 01R	01L 01R	95	99	100
20.7%	D-01-MVFR-02	West	MVFR	28R	28R	28L	28L	81	81	83
9.8%	D-01-IFR-02	West	IFR	28R	28R	28L	28L	56	61	61
3.1%	D-01-MVFR-01	West	MVFR	28L 28R	28L 28R	01L 01R 28L 28R	01L 01R	87	90	93
2.8%	D-01-IFR-01	West	IFR	28R	28R	01L 01R 28L	01L 01R	56	62	62
1.7%	D-02-VFR-01	East	VFR	19L 19R	19L 19R	10L 10R	10L 10R	77	77	77
1.4%	D-01-SOIA-01	West	MVFR	28L 28R	28L 28R	01L 01R 28L 28R	01L 01R	75	81	81
1.1%	D-02-MVFR-02	East	MVFR	19L 19R	19L 19R	19L 19R	19L 19R	53	55	54
0.5%	D-01-SOIA-02	West	MVFR	28R	28R	28L	28L	75	80	81
0.4%	D-02-MVFR-01	East	MVFR	19L 19R	19L 19R	10L 10R	10L 10R	56	56	56
0.1%	D-01-IFR-04	West	IFR	28R	28R	28L	28L	40	40	40
0.1%	D-02-IFR-02	East	IFR	19L	19L	19L 19R	19L 19R	52	52	50
0.1%	D-01-IFR-03	West	IFR	28R	28R	28L	28L	45	45	45
0.1%	D-02-IFR-01	East	IFR	19L	19L	10L 10R	10L 10R	53	53	52

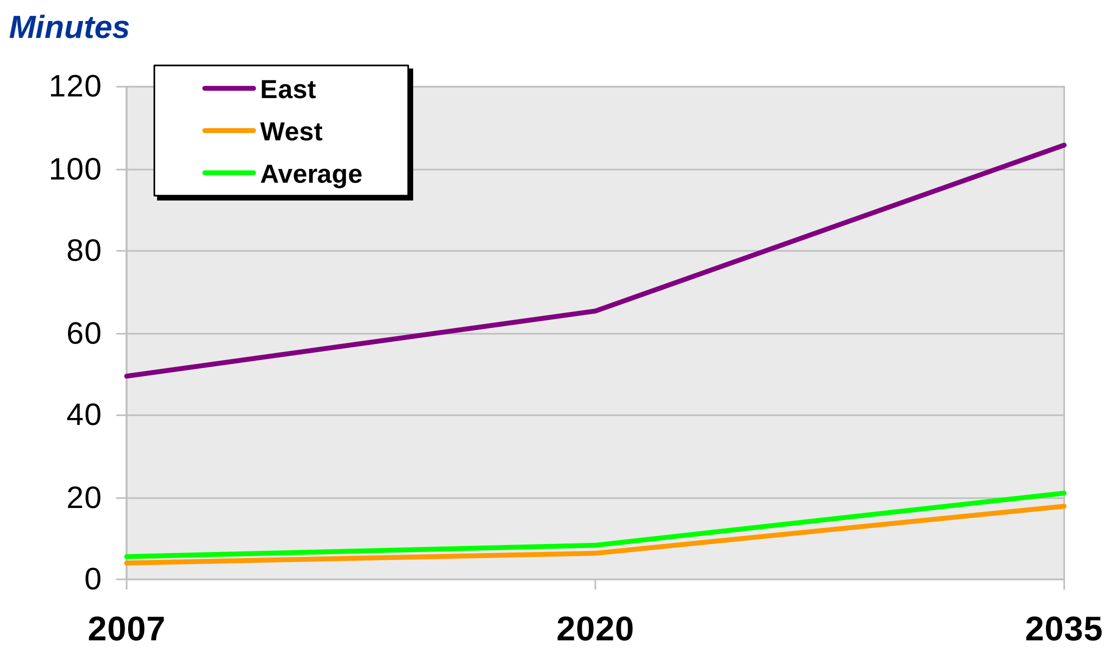
Note: The baseline capacity analysis does not assume any improvements to SOIA procedures.

In 2035, Average Delay at SFO Reaches 21 Minutes, and Average East Flow Delay Exceeds 100 Minutes

- **SFO operates to the West 93% of the time**
- **East flow VFR capacities are generally much lower than West flow**
- **East flow generally occurs during stormy winter weather**

Average Minutes of Delays by Major Operating Conditions

Baseline 2007 and Forecast 2020 and 2035

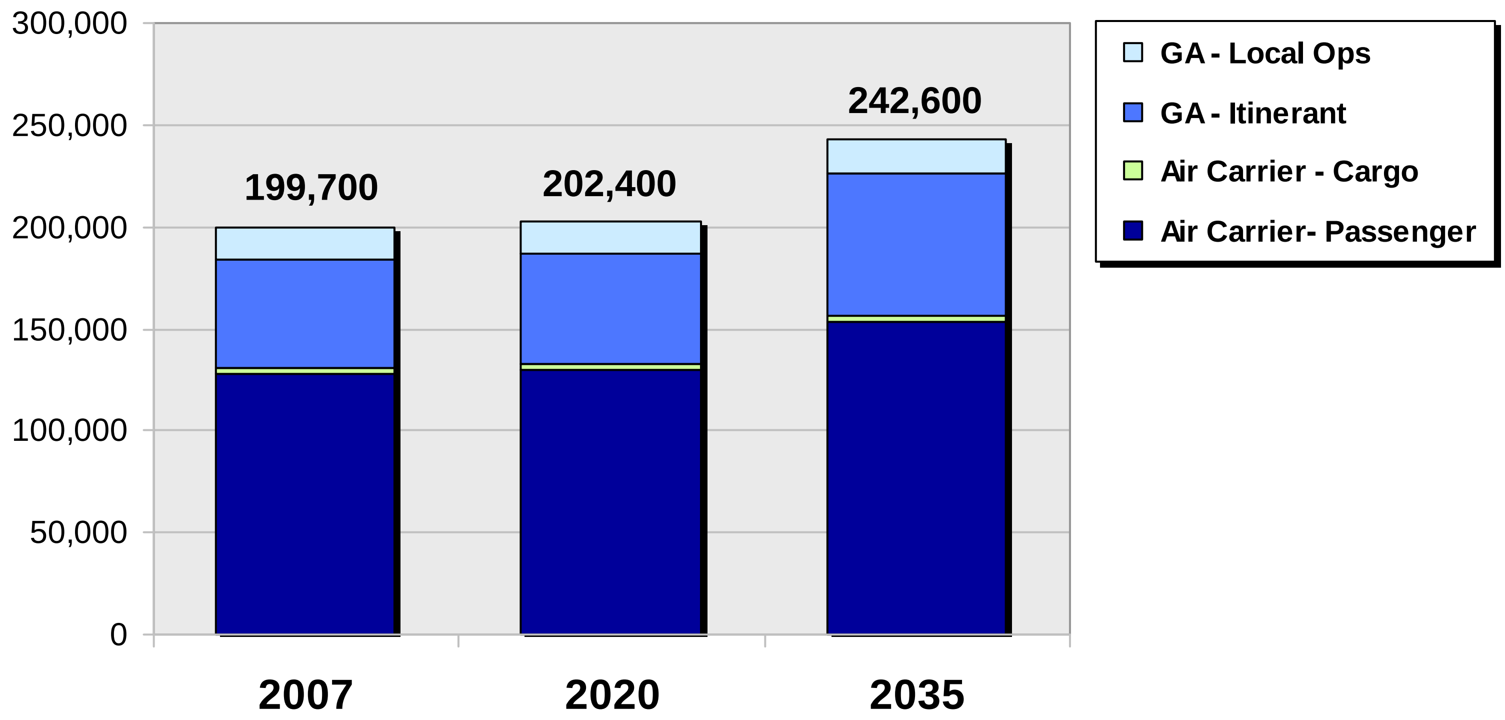


Note: 2007 capacities = 95 VFR and 56 IFR; 2020 capacities = 99 VFR and 61 IFR

SJC's Runway Demand is Forecast to Increase by 21% from 2007 to 2035

Annual Aircraft Operations

Baseline 2007 and Base Case Forecast 2020 and 2035



Note: Excludes military operations.

Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009

Over the Forecast Period, Large Jets Become More Prevalent at SJC, Increasing from 47% to 56% of Aircraft Activity

Annual Operations by Aircraft Weight Class and Type

Baseline 2007 and Base Case Forecast 2020 and 2035

Weight Class	Type	Percent of Annual Operations 2007	2020	2035
Small	Jet	6.6%	6.1%	6.4%
	Non-Jet	19.3%	16.4%	14.7%
	Subtotal	**25.9%**	**22.5%**	**21.1%**
Large	Turboprop	3.4%	2.7%	2.4%
	Jet	46.9%	50.1%	56.1%
	Regional Jet	20.5%	16.4%	18.8%
	Subtotal	**70.8%**	**69.3%**	**77.4%**
Boeing 757	**Jet**	**1.8%**	**7.1%**	**0.4%**
Heavy	**Jet**	**1.5%**	**1.1%**	**1.1%**
Total		100.0%	100.0%	100.0%

Notes: Small = <44,000 lbs; Large = >44,000 lbs and < 300,000 lbs; Heavy = > 300,000 lbs

Excludes military operations.

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Source: Regional Airport System Plan Update – Baseline Aviation Activity Forecasts for the Primary Bay Area Airports, August 27, 2009

At SJC More than 80% of Operations are Conducted Under Optimal Weather (VFR) Conditions

Modeled Capacities of Runway Configurations

Baseline 2007 and Base Case Forecast 2020 and 2035

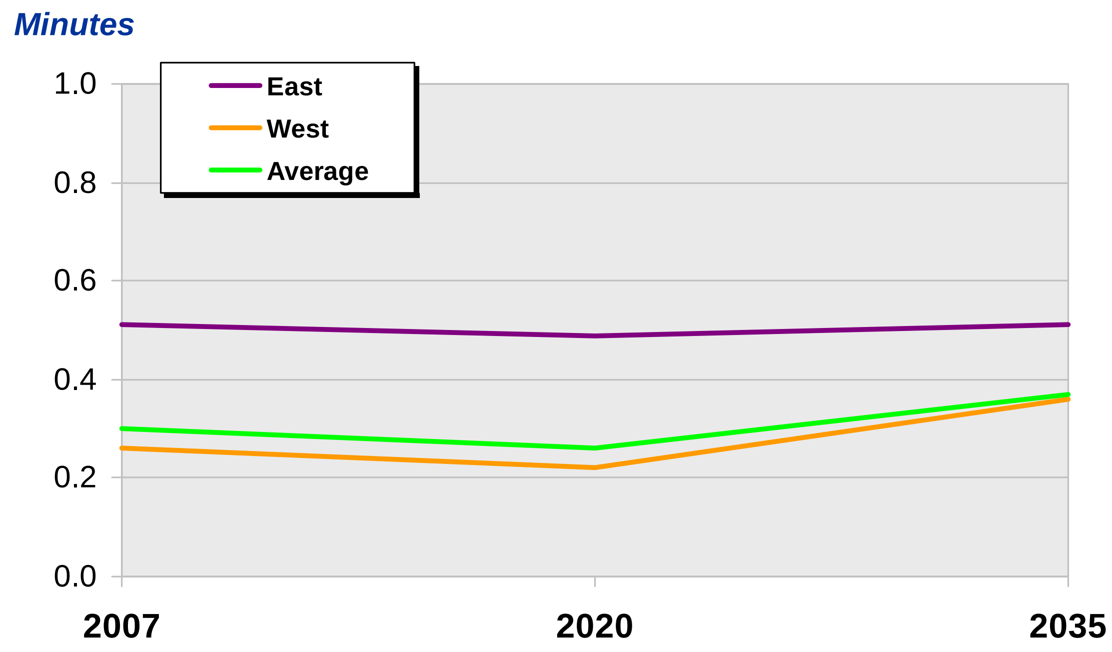
				Runways				Capacity (ops/hr)		
Percent of 2007 Ops	Configuration ID	Flow	Weather	Jet Landings	Non-Jet Landings	Jet Take-offs	Non-jet Take-offs	2007	2020	2035
80.8%	D-01-VAPS-01	West	VFR	29 30L	29 30L	30R	29 30R	92	98	103
12.0%	D-02-MVFR-01	East	MVFR	11 12R	11 12R	12L	11 12L	62	63	64
3.1%	D-02-VAPS-01	East	VFR	11 12R	11 12R	12L	11 12L	89	96	98
2.5%	D-01-MVFR-02	West	MVFR	29 30L	29 30L	30R	29 30R	62	63	65
1.3%	D-01-IFR-01	West	IFR	30L	30L	30R	29 30R	54	59	59
0.2%	D-02-IFR-01	East	IFR	12R	12R	12L	11 12L	53	58	58

SJC's Average Delay is at Less than One Minute in East and West Flows

- SJC operates to the West 93% of the time
- SJC East flow capacities are equal to or greater than West flow for some configurations
- Adjustments have been made to Delaysim analysis to prefer West flow when winds are light

Average Minutes of Delays by Major Operating Conditions

Baseline 2007 and Forecast 2020 and 2035



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