ANALYZING THE OPERATIONAL CAPACITY EFFECTS OF THE MONITOR ALERT PARAMATER (MAP)

Kevin Hanson, John Gulding, Federal Aviation Administration, Washington, D.C.
Abbas Afshar, Metron Aviation, Inc., Dulles, VA.

Abstract

The FAA's Air Traffic Organization (ATO) Office of Performance Analysis is responsible for developing indicators and providing analysis on the operational efficiency of the NAS and to ensure its databases provide the necessary information for linking performance to root causes. The focus of this paper is the primary indicator of capacity within a sector, the Monitor Alert Parameter (MAP), an indicator designed to alert personnel when traffic levels in a given sector may be at a level that will affect the efficiency of the system. Over the past decade, however, it has come under some criticism for being too simplistic in its calculation with the obvious implication that some MAP values do not represent the real trigger point at which the balance between sector capacity and traffic volume require a closer look. A search for studies on this subject yields sparse results with cursory connections. This paper will review and analyze the current FAA policy for MAP and discuss the challenges and potential shortfalls of the current implementation of baseline MAP values. Further, it will discuss the challenges associated with measuring the effectiveness of this tool. Finally, this paper draws conclusions and makes recommendations focused on enabling a more comprehensive analysis of sector capacity limitations on the efficiency of the NAS.

Managing Demand and Capacity Imbalances in the NAS

To ensure both the safety and efficiency of the NAS, Air Traffic Control Specialists (ATCS) and Traffic Management (TM) personnel must ensure an appropriate balance between airspace demand and capacity. To accomplish this, both ATCS and TM must have the appropriate tools to analyze and identify demand and capacity imbalances and to alert them when action is needed to avoid potential safety risks. Traffic volume and capacity must be managed in all phases of flight; while airborne or on the ground. At airports, capacities are generally determined by airport configuration, runway space, terminal space and other physical constraints that, along with weather, limit an airport's ability to send and receive flights. In practice, this capacity is indicated by the called airport arrival rate (AAR) and the airport departure rate (ADR), which represent the rates at which airports can accommodate landing and departing aircraft. In the air, and particularly in the en route segment of a flight, traffic is managed at the sector level and thus the constraint exists at that level. Typically, the airspace capacity limitation is not the physical limitation of insufficient airspace to safely separate aircraft, but a limitation on how many aircraft controllers are able to safely manage. This limitation is reflected in the MAP, which is not a set capacity limitation, but a trigger to indicate when the traffic may reach a level that will reduce a sector's efficiency.

As there are thousands of airports and sectors across the NAS, strategically balancing the constraints across all of them is extremely complex and nearly impossible to consolidate into digestible pieces of information that a controller can use. To aid in this air traffic management challenge, the FAA developed Flow Evaluation Areas (FEA) and Flow Constrained Areas (FCA). FEAs/FCAs are set up to measure the rate of traffic flowing into a NAS element (i.e. approach control or airport) or other area defined by a line or shape that represents the area of concern with associated filters to define the traffic flow into the given area. An FEA is used to evaluate potential problem areas while an FCA has a constraint associated that requires stakeholders to take action. The FEAs/FCAs are not actually areas where demand exceeds capacity but are used as a proxy for balancing the demand and capacity for the multiple airports and sectors that are impacted by the flow the given FEA/FCA is intended to monitor. Like MAP, FEA/FCA limits are not hard constraints, but indicators of periods of high traffic that may negatively impact efficiency at affected airports, sectors, ARTCCs or other areas. FEA/FCA baseline limits have been developed by facilities over time to ensure that effected airports and sectors are not overloaded as a result of a high number of aircraft entering the FEA/FCA during a given period of time.

These potential NAS demand and capacity imbalances are indicated for three different categories: (1) Airport constraints via the AAR and ADR, (2) Sector constraints represented in MAP and (3) FEA/FCAs which allow ATCS and TM personnel to strategically balance multiple NAS constraints. These three types of indicators are integrated into two systems that TM personnel monitor: Traffic Flow Management System (TFMS) and Flight Schedule Monitor (FSM).

TFMS forecasts traffic loading across sectors and indicates when sectors are forecast to be near or above MAP. Figure 1 shows the forecast sector loading for ZMA sector 25. The bar on the top indicates that most of the day will be well below MAP loading as indicated by the green boxes. There is one time period forecast to exceed MAP, indicated in red, and two time periods forecast to be near MAP as indicated by the yellow boxes.

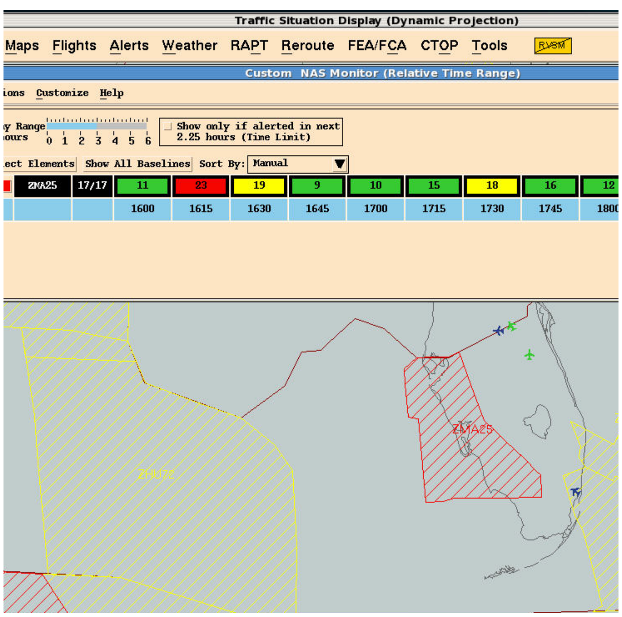

Figure 1. TFMS Sector Loading Forecast for ZMA Sector 25

FSM monitors both the forecast loading at airports and across FEAs/FCAs enabling TM to look out several hours in advance to identify potential high volume issues. Figure 2 displays an FEA implemented near Houston to monitor traffic through an area of convective weather. The forecast load across this FEA is seen at the top of the screen in grey.

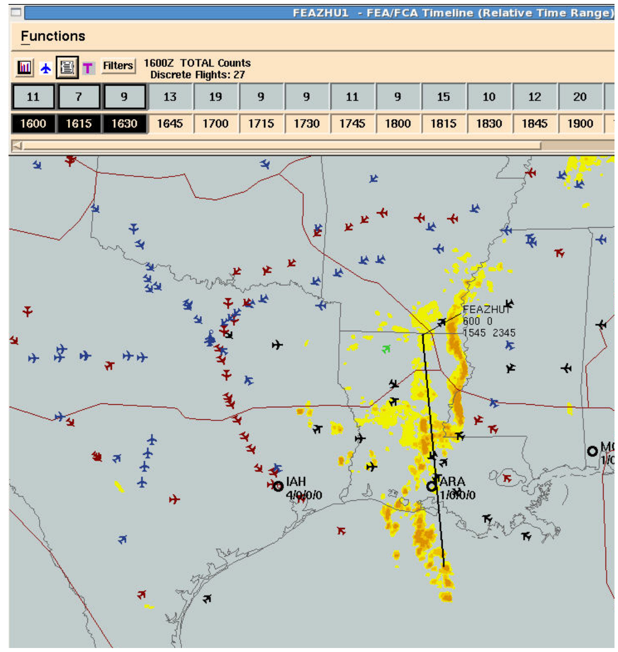

Figure 2. FEA loading forecast in FSM

The Monitor Alert Parameter

MAP is an essential part of the integrated traffic management system described above. Over the past decade, however, it has come under some criticism for being too simplistic in its calculation with the obvious implication that some MAP values do not represent the real trigger point at which the balance between sector capacity and traffic volume require a closer look. A search for studies on this subject yields sparse results with cursory connections. For this reason, the primary focus of this paper is to analyze the calculations and implications of current MAP setting policy.

FAA Policy

Policy for determining MAP values is published in FAA Order JO 7210.3Z: MAP was established as a "numerical trigger value to provide notification to facility personnel, though the Monitor Alert (MA) function of TFMS, that sector/airport efficiency may be degraded during specific periods of time. The efficiency of a functional position or airport in providing air traffic services is a shared responsibility of the TM team. That team consists of the ATCS(s), operations supervisor (OS), and the Traffic Management Unit (TMU). These entities must monitor, assess and act on sector/airport loading issues to ensure that these NAS elements operate efficiently."

MAP was designed to enable ATCS(s), OS(s), and the TMU to monitor the workload of a sector based upon the amount of traffic a controller can effectively manage. The baseline values for MAP are established assuming a controller needs to devote 36 seconds of time to each aircraft controlled. To calculate the number of aircraft a controller can effectively control in a sector, the average number of minutes traversing aircraft spend in a sector is divided by 3/5 (36 seconds is three-fifths of a minute). The results of this calculation are rounded and tabled in the FAA order (see Table 1). Additionally, the maximum allowable baseline MAP value was set at 18 and these baseline MAP values can be adjusted by +/-3. A process also exists to make adjustment greater than three.

Table 1. FAA Determined Map Values

Ave Sector Flight Time	MAP Value
3 min	5
4 min	7
5 min	8
6 min	10
7 min	12
8min	13
9 min	15
10 min	17
11 min	18
12 min or greater	18

Implementation at ARTCCs

As discussed above, MAP values are integrated with traffic levels that are projected to occur by the TFMS system. These forecast traffic projections are based upon filed flight plans when available or historical flight plan tendencies if a flight plan has not yet been filed. These projections afford the Front Line Manager (FLM) and TMU personnel the ability to monitor potential demand/capacity imbalances and react accordingly. Time periods when traffic levels are forecast to be below MAP are indicated in green in the TFMS system as seen in Figure 1. As loading approaches MAP it becomes yellow and time periods where the traffic is forecast to be above MAP are indicated with red.

At all levels of alert, FLMs and TMU personnel are required to monitor all sector MAP statuses within their area of responsibility. When the MAP value is alerted, either red or yellow, they must evaluate the impact and take appropriate action depending upon the severity of the expected impact. MAP exceedances, and in some cases the FAA response to the exceedance, are recorded in the National Traffic Management Log (NTML). Typically, remedial actions include choosing to accept the high loading for a short time period, splitting the sector or assigning an additional controller for the time of the increased traffic. In exceptional cases where these actions do not suffice, the facility can request other Traffic Management Initiatives (TMI) including Miles in Trail (MIT), Ground Delay Programs (GDPs), Airspace Flow Programs (AFPs), Airborne holding, or other initiatives such as offloading traffic via a reroute or tactically offloading aircraft. These types of actions, if they result in delays greater than 15 minutes, should be recorded in the FAA OPSNET system.

Known MAP Shortfalls

The basic assumption behind the calculation of MAP appears to be valid: The amount of aircraft a controller can effectively manage is based on two factors, (1) the amount of time a controller spends on each aircraft in the given sector and (2) the amount of time aircraft spend in each sector. For example, if a controller requires 30 seconds for each aircraft and each aircraft is in that given sector for 1 minute, the controller can effectively manage two aircraft. This assumption has not been disputed.

However, in its implementation, the calculation assumes that the first factor is the same across all sectors (36 seconds as seen in the policy above) while directly measuring the second factor for each sector individually. While not explicitly stated, this simplification is undoubtedly due to the lack of data on the amount of time spent with each aircraft for every sector in the NAS. Conversely, it is relatively simple to calculate the average time aircraft are spending in any given sector with data that is widely available.

As a result of this over simplification caused by lack of data, there are two potential negative effects. First, the calculation may *overestimate* the amount of aircraft that can be effectively managed in a complex sector, such as one where two flows of traffic are merging and the aircraft require more attention than a typical sector. Second, the calculation may *underestimate* the amount of aircraft that can be effectively managed in the simple sectors where all aircraft are flying in the same direction and altitude for the entire transit through the sector and thus require less individual attention. As a result, there is the potential to overload sectors in the first case or to unnecessarily constrain the system in the second.

Two further shortfalls of MAP have come up during conversations with TM personnel. While these shortfalls were not the focus of this paper, they should be noted for further study:

(1) There is a requirement for dynamic adjustment of MAP "to reflect the ability of the functional position to provide air traffic service. During periods of reduced efficiency the MAP will be dynamically adjusted downward and conversely, when efficiency is improved, the MAP will be adjusted upward." Based upon anecdotal evidence, this "dynamic adjustment" is typically not done automatically for instances where it conceivably could be, such as during a weather event, nor is it reflected in TFMS when TM personnel do knowingly reduce their traffic density threshold due to conditions.

(2) There is no guidance on assigning MAP values to sectors when they are split or combined.

MAP Calculations

FAA Order JO 7210.3Z directs that "Average sector flight time will be calculated using data indicating functional position operations for a consecutive Monday through Friday, 7:00 AM - 7:00 PM local time frame." Each Air Route Traffic Control Center (ARTCC) has the responsibility for implementing its MAP values in compliance with policy and the FAA's Performance Data Analysis and Reporting System (PDARS) produces reports for each center that comply with the FAA policy on determining MAP values. For the purposes of this paper, the PDARs report provided a sound baseline for measuring calculations against, but did not provide analysis of the data behind the report.

In order to enable further analysis of the amount of time aircraft are spending in a sector, the authors used TFMS flight trajectory data and ARCGIS shape files for sectors in ZMA (Miami ARTCC) to produce a table of entry and exit points for all trajectories for the Months of February, July, October, November and December of 2015 as sample cases. These tables represent 779,095 flights intersecting 42 sectors during these 5 months of analysis. The ZMA sectors can be seen in Figure 3, which does not represent all of the sectors as several of them are vertically layered over/under each other.

Figure 3. ZMA Sectors

Determining MAP values

The definition provided by FAA Order JO 7210.3Z for calculating the average sector flight time for MAP does not specify all the information needed for accurate and robust average sector flight time calculations. As a result, some assumption had to be made to execute the calculations. Additionally, the guidance speaks only of obtaining average time and does not address many of the practical considerations often used in getting a single value (i.e. average) to represent the entire population of flights or all operating flows in a sector.

This paper analyzes five different aspects of the current implementation of MAP:

(1) The effects of implementing the 7:00 AM - 7:00 PM criteria including both the conditions for inclusion/exclusion of flights and the effects of changing the criteria to different hours of the day.

(2) The effects of not setting an outlier parameter for minimum flight time in a sector.

(3) The importance of the choice in the week analyzed for setting baseline MAP values.

(4) The similarity/differences in the distribution of flight times between sectors.

(5) A comparison of actual MAP values to baseline MAP calculations.

The Effects of the 7:00 AM - 7:00 PM Criteria

There are two aspects of this assumption that were analyzed: First of all, when calculating the average time in a sector, a choice has to be made about the 7:00 AM limit for start time. For example, does it imply only flights entering after 7:00 AM, or does it include flights that entered before but remained after 7:00 AM? This research sought to determine the sensitivity of the average to that basic assumption. Second, the decision to use 7:00 AM to 7:00 PM appears to be an attempt to use a core operating day. Since the order FAA, has adopted a concept of "Core Hours" for performance that addresses facilities such as Memphis where traffic peaks after 7pm and before 7am. This paper looked to determine how sensitive the calculation is to that choice for sectors in ZMA.

Inclusive/Exclusive

As stated, how boundary conditions for cutoff times are to be implemented is not clearly defined in the FAA Order. In addition to the example above, it is not clear if a flight entering a sector before 7:00PM but exiting the sector after 7:00PM should be considered in the calculations.

We compared two cases for this analysis: (a) Excluding flights entering a sector before 7:00 AM and flights exiting the sector after 7:00PM local time and (b) including flights as long as they were inside the sector between 7:00AM and 7:00PM. Table 2 summarizes the difference between scenarios (a) and (b) for the week of October 5^{th} through October 9^{th} 2015 across all sectors in ZMA center. Although only one week could be displayed, all analyzed weeks showed similar trends.

Table 2. Comparison of Including/Excluding Boundary Times

Avg difference in flights for (a) and (b)	22.5
Max difference in flights	73
Avg difference as % of flight counts	2%
Max difference as % of flight counts	6%
Avg diff of avg sector flight times (min)	0.09
Max diff of avg sector flight times (min)	0.33
Avg diff as % of sector flight times	1%
Max diff as % of sector flight times	4%

By being inclusive of flights that enter before or exit after the cutoff times, the flight counts for the 5 day week increased on average by 22.5 when compared to flights counts not including these flights. The maximum difference observed for the week was 73 flights for a given sector and maximum percentage of difference in flight counts was 6%.

Focusing on the average flight times of all flights within a sector for the same week, Table 2 illustrates that the average flight time changed only by 0.09 minutes on average and the maximum difference was only 0.33 minutes which accounted for 1% and 4% of average sector flight times. Similar results were found for other weeks that were analyzed.

While these results were not surprising, they do allow for the conclusion that while analysts may desire clarification on how to calculate the average, the inclusivity/exclusivity of the cut-off times appears to be inconsequential.

Time of Day Selection

Aside from being inclusive or exclusive of 0700-1900 boundaries, we analyzed the effect of selecting the hours from 0700 and 1900. To do so, we calculated the average sector flight time between 0700 and 1900 on an hourly basis for all sectors in ZMA for the week of October 5^{th} to 9^{th} 2015. For instance, the average hourly flight time between 0800 and 0900 is calculated as the average sector flight time of all flights that were inside a given sector for more than 60 seconds between 0800 and 0900 in any day of the analyzed week. Figure 4 presents the hourly flight time average for 3 select sectors (Sector 3, 4, and 46).

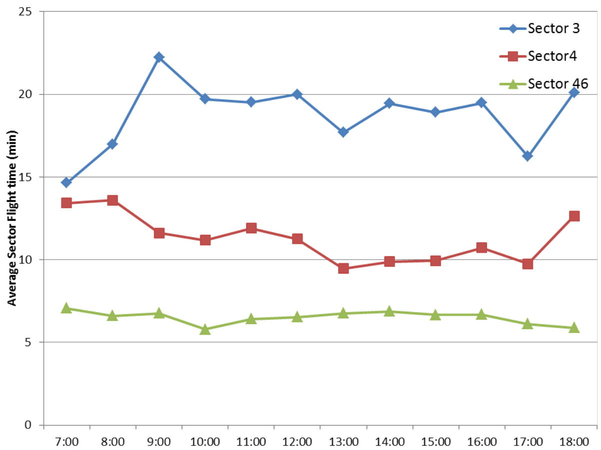

Figure 4. Hourly Sector Flight Times

Figure 4 highlights the variations of average sector flight time throughout the core operating day. Sector 3 has the largest variations, Sector 4 has large variations contrary in nature to those of Sector 3; and Sector 46 had the most stable profile. Table 3 summarizes the variations in hourly average flight time.

As seen in Table 3, the difference between single hour averages and the 12 hour average can be as high as 50% depending on the sector. Therefore, the hours chosen for MAP calculations have a significant impact on the baseline MAP value. Depending on the hourly average chosen, the MAP values could potentially swing between 12.6 to 2.1 points depending on the sector. It must be noted that while the MAP calculation would change by as much as 12.6 for sector 3, this full amount would not be realized as the maximum baseline MAP is capped at 18. Further work is required to address effects of traffic outside these hours and facilities where traffic peaks during nighttime hours.

Table 3. Hourly Flight Time Variations

Sector	3	4	46
Avg Flight Time (7am-7pm)	15.51	9.93	6.34
Max Diff in Hourly Flight Times (mins)	7.58	4.14	1.27
Percent Diff to 12hr avg	48.9%	41.7%	20.1%
Map implications due to Hourly fluctuations	12.6	6.9	2.1

Minimum Flight Time Parameter

During the analysis we found that there were a number of flights that were only in a sector for a very short period of time, some even as brief as one second. Clearly, if an aircraft is only in a sector for one second, the sector did not take control of that aircraft and it just briefly intersected the airspace. This realization, however, requires an analyst to make an assumption on the minimum dwell time to include when calculating the average dwell time of a sector. For this paper, we wanted to determine the impact of minimum dwell time criteria. With the exception of this section, the analysis for this paper was done under the assumption that flights with a dwell time less than 60 seconds would be excluded.

In this section we analyzed two cases: (a) Including all flights that cross a sector's boundaries regardless of amount of time spent in the sector, and (b) Excluding the flights with sector flight times of less than 60 seconds. Table 4 summarizes the difference between the two cases for the week of October 5th through October 9th 2015 across all sectors in ZMA.

When comparing the two cases, we found that excluding the flights with short (less than 60 seconds) sector flight time resulted in excluding on average 65.7 flights from each sector (7% of total traffic) with a maximum difference of 308 flights or 28% of all traffic for that sector. Excluding these flights with short sector flight times increased the average sector flight time by 0.61 minutes on average (7% of average sector flight time across all sectors). The effect of excluding short flight times was not uniform across the sectors as some sectors were marginally affected while the maximum effect was an increase of 27% in average sector flight time.

Table 4. Effects of Excluding Flights with Minimum Dwell Times

Avg. flights excluded per sector	65.7
Maximum flights excluded	308
Avg. flights excluded as % of flight counts	7%
Max flights excluded as % of flight counts	28%
Avg diff of avg sector flight times (min)	0.61
Max diff of avg sector flight times (min)	1.99
Avg diff as % of sector flight times	7%
Max diff as % of sector flight times	27%
Avg diff in MAP due to short flights	1.0
Max diff in MAP due to short flights	3.3

As expected, excluding flights with short sector dwell times, case (b), results in a higher average calculated flight time and therefore a higher MAP value. In our sample analysis, excluding sector flight times of less than one minute resulted in a calculated MAP value which was 1.0 point higher than if they were included, with the highest impact being on a sector with a calculated MAP of 3.3 higher. Clearly this assumption has a significant impact on the calculation of baseline MAP and may require additional analysis to determine the correct minimum sector flight time for inclusion.

Choice of Week's Effect on MAP Calculations

While the FAA's guidance is clear on calculating baseline MAP based upon weekday traffic, it is unclear how important the choice of week is, or if any week will do. The policy implies that a single 5-day week of traffic, at any time of the year, is sufficient for establishing representative flight times. For this paper we analyzed two aspects of this question: Do weeks presumed to be similar in nature, for example the four weeks in October, vary greatly amongst each other? And second: Is there a large variation in average dwell time that changes along with the known increases/decreases in traffic during different seasons of the year?

Differences in Weeks within Same Season

In order to investigate the potential variations among weeks assumed to be of like nature, we analyzed all flight trajectories that intersected ZMA sectors during 7 consecutive Monday-Fridays in October and November of 2015. Table 5 summarizes the variations between the 7 consecutive weeks in the same October-November season (the last week of November was excluded due to the Thanksgiving Holiday). Table 5 highlights the fluctuation among the weeks. On average, the flight counts fluctuated 24% and the maximum difference was 59% for a given sector. Similarly, the average sector flight time fluctuated 11% on average with a maximum difference of 48% in average flight times.

Table 5. Variations Among the Weeks in the Same Season

Avg diff of sector flight counts	256
Max diff of sector flight counts	606
Avg diff as % of flight counts	24%
Max diff as % of flight counts	59%
Avg diff of sector flight times (min)	1.14
Max diff of sector flight times (min)	2.74
Avg diff as % of sector flight times	11%
Max diff as % of sector flight times	48%
Avg diff in MAP among the weeks	1.9
Max diff in MAP among the weeks	4.6

Looking at potential differences in calculating MAP values, Table 5 underscores the importance and difficulty of selecting a week that is a good representative. On average, calculated MAP values have a difference of 1.9 depending on the week chosen for calculation. This difference was as high as 4.6 for a given sector using only 7 weeks from the same season. These results showed more variability than expected and indicate current guidance on flight sampling and use of averages will need improvement in order to effectively determine MAP parameters.

Seasonal Variations

We further investigated the seasonal variability by analyzing flight trajectories from February, July, October and December of 2015. For this effort, in accordance with the policy, we calculated the average flight time for each consecutive Monday through Friday within each month and during the specified timeframes. Each month then had average sector flight times for four weeks and these were averaged (weighted by the amount of flights in each week) to give the average sector flight time for each month.

Table 6 presents the average monthly values for Sector 3, Sector 46, and the average over all sectors. It is evident that traffic volumes vary greatly depending on the season with winter months being busier than other times of the year. This was expected considering the higher demand for travel to Florida and the Caribbean in the winter.

Table 6. Seasonal Variability

Month in 2015	FEB	JUL	OCT	DEC
Avg flt count (Sec 3)	716	618	680	690
Avg flt time (Sec 3)	11.12	15.51	14.90	13
Avg flt count (Sec 46)	1904	1418	1443	1665
Avg flt time (Sec 46)	6.13	6.08	6.28	6
Avg flt count (all sectors)	1368	1146	1049	1260
Avg flt time (all sectors)	12.77	12.59	12.77	13

Nevertheless, the average sector flight time does not follow the same seasonal pattern as traffic volumes. Some sectors, such as Sector 3 showed a large variation among monthly averages while other sectors (e.g. Sector 46) had little variations in their flight times. Additionally, it is worth noting that we did not see a clear correlation between traffic volumes and average sector flight times. For example, Sector 3 in February had the highest traffic volume but the lowest sector flight time among the months analyzed and the month of July had the least traffic but the highest average sector flight time in the case of Sector 3.

There does appear to be a seasonal aspect to the average flight time within each sector. However, this finding is complicated by the fact that this seasonality appears to be unique for each sector.

Sector Flight Time Distributions

By policy, the MAP value for a sector is solely a function of average flight times for all flights that traversed the sector in the chosen week (Mon-Fri 7am-7pm local). The simplicity of the formula could be considered its advantage; however, it may be ignoring the variations and predictability of flight times within a sector and underestimating the complexity of the system which can have a major effect on controller's workload capacity.

The following analysis looks at this variability of times and assesses the degree to which average values are representative of the complete population and traffic scenarios a sector would experience. This assessment focused on 5 sectors inside ZMA (Sector 3, 4, 19, 43, 46) and analyzed their flight times for the week of October 5th to 9th 2015.

Table 7 presents statistics for flight times in the selected sectors. A comparison of the Average and the Median provides an indication of how truly representative the average sector time is of the typical flight. Sector 3 had the largest discrepancy between the two statistics with an average flight time of 15.51 minutes and a median flight time of 10.41 minutes. Similarly, Sector 4 had a large discrepancy between the two while the other 3 sectors did not see such large discrepancies with Sector 46 having a relatively small discrepancy with an average of 6.34 minutes and a median of 5.76 minutes.

Table 7. Flight Time Statistics within a Sector

Sector	flight count	Avg	Med	Std dev	15 perc	85 perc
3	696	15.51	10.41	15.74	2.82	27.35
4	1002	9.93	5.00	10.19	1.65	22.10
19	421	16.00	18.27	7.04	9.10	21.82
43	713	24.60	25.58	10.52	13.23	31.87
46	1498	6.34	5.76	3.55	3.72	8.78

The comparison between average and median is important since the formula for calculation of MAP values assumes that a controller can handle more flights when the flights are in the sector for longer. In other words, the shorter average flight times reduces the capacity of the sector because the controller has a smaller window between entry and exit points to communicate with the flight. As a result, if a large portion of flights in a sector have shorter than average flight times such as in Sector 3 and 4, that would essentially reduce the sector capacity and MAP value. However, the current policy to calculate MAP values does not consider this.

It is evident that Sector 3 and 4 entail higher degrees of variations and complexity of operations relative to Sectors 19 and 43 and it can be argued that using median is a better approach than average sector flight times since the average could be affected more easily by very short or very long flights that could be considered outliers. In any case, the large difference between average and median sector flight time is cause for concern.

Additionally, Table 7 displays three measures of the variation within the data: the standard deviation, the 15th percentile and the 85th percentile. The 15th percentile represents the value at which 15% of the data is less than this value. Likewise, 15% of the data is greater than the 85th percentile. As such, 70% of the data exists between the two values. In this case, as with most, there is a high degree of correlation between a large standard deviation and a large gap between the 15th and 85th percentiles. Sector 3, which again is one of the extremes, has a standard deviation of 15.74 minutes with 70% of its values between 2.82 and 27.35. Sectors 4, 19 and 43 also have surprisingly large variations within their data.

Figure 5 of a Flight Time histograms and Figure 6 of Flight Time percentile distributions provide a visualization of the variability of this measure. Both charts show many of the flight times are above 11 minutes and potentially outside the domain of the guidance. Figure 5 shows a normalized histogram of flight times for each of the 5 sectors in 10-minute time bins. Each of the five selected sectors has a distinct distribution of flight times which is representative of the diverse nature of the ZMA sectors. For example, in Sector 3 about 50% of flights have a sector flight time of less than 10 minutes followed by 25% in the 10-20 minutes range with a right tail that gradually drops except for a jump at the 60+ minutes range. In Sector 4, the majority (about 65%) of flights have a very short flight time. In sector 4, about 35% of flights have a flight time between 10 and 40 minutes and there are a negligible number of flights that have longer flight times.

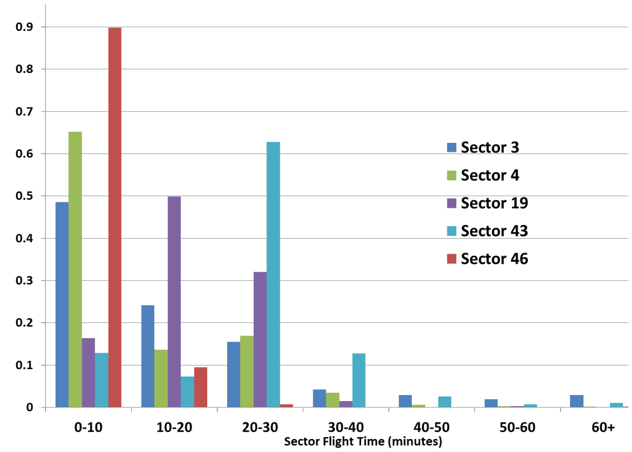

Figure 5. Sector Flight Time Distributions

Sector 19 is different from other sectors since the majority of flights have a flight time of 10-20 minutes. Sector 19 has the least variation in flight times and more than 98% of flights fall within the 10-20 minute time bin or the one immediate bin before or after. Sector 43 has the highest average flight time among the 4 sectors. More than 60% of flights have a flight time in 20-30 minutes range with rest of the flights distributed relatively evenly among other time bins. Current guidance caps MAP calculations at 11 minutes, presumably under the assumption that 18 aircraft marks the upper limit that a controller in a sector can handle. However the nature of the long dwell times may require very different workloads and this should be further researched in updating the FAA order.

Figure 6 shows the cumulative flight time distributions for the same 5 sectors as Figure 5. On this chart, the line indicating the sector flight time associated with the maximum allowable baseline MAP calculation, 11 Minutes, is delineated by the straight blue line. Each sector's distribution also has its mean, median and the average flight time associated with its implemented MAP marked. For Sector 3, shows no area of similar flight times, unlike Sector 43, which levels off between the 25th and 75th percentile in a relatively horizontal line of flight times between 23 and 28 minutes. Three of the distributions have a mean higher, or to the right, of the median values and two are less. Quite apparent is the disconnect between the point associated with the implemented MAP value and the mean flight time.

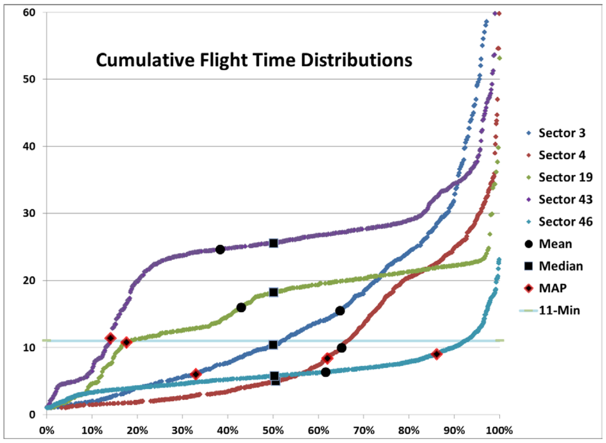

Figure 6. Cumulative Flight Time Distributions

For Sector 46, the most stable of the sectors displayed, the mean flight time is associated with the 62nd percentile, but the locally adjusted MAP is associated with the 86th percentile of the distribution. For Sector 3, the mean value is associated with the 65th percentile, but the locally adjusted MAP corresponds to the 33rd percentile of the data. Only sector 4 has a close relationship between the mean value and the associated MAP near the 63rd percentile.

Clearly, the analysis shows the difficulty in developing a single value to describe the flight time distribution of a sector. This calls into question the current FAA Order classifying a Sector based upon its average flight time alone.

Implemented MAP Values

These insights led us to question how the calculated MAP values being analyzed compare to the MAP values implemented at ZMA for these sectors. Table 8 summarizes the calculated versus published MAP values for selected Sectors in the ZMA center based on the flight trajectories from the week of October 5th to 9th, 2015.

Table 8. Calculated vs Published MAP

Sector	Average Time	Calculated MAP	Published MAP	Diff
3	15.51	18.0	10	-8.0
4	9.93	16.5	14	-2.5
19	16.00	18.0	18	0.0
43	24.60	18.0	19	1.0
46	6.34	10.6	15	4.4

Sector 3, again, immediately stands out. Its calculated MAP value is capped at the maximum of 18, however the facility has dramatically reduced the MAP value to 10. Similarly, but not nearly as drastically, the published MAP value for Sector 4 is lower than its calculated MAP value. We do not yet have any visibility on the reasoning behind this apparent change made by ZMA, but it is interesting to note that by any measure the variability of flight times within Sector 3 was very high. Sector 4 had high variability as well, but it was more in line with Sector 43's variability apart from the observation that sector 4 had a large difference between mean and median while sector 43 did not.

Sectors 19 and 43 have the least difference between calculated and published MAP values. Sectors 19 and 43 have unique characteristics. They both have high averages, high medians and their 15 percentile values are relatively high as well which indicates the majority of flights are uniformly long flights and there are very few short flights. Therefore, the complexity of operations is relatively low and well captured by using the average flight time and the standard MAP value calculation. The small difference between published and calculated MAP values confirms this conclusion.

Finally, Sector 46 apparently increased its MAP value from the calculated value. The calculated MAP value for Sector 46 is 10.6, while the implemented value has been raised to 15 by the Center. A closer inspection of the variability within Sector 46 appears to explain this. Sector 46 has the lowest average flight time which should translate into a low MAP value. Referring to Table 7, it is apparent that Sector 46 has a very small standard deviation of flight times and the difference between 85 and 15 percentile values are the lowest of all sectors. It seems that even though the flights in Sector 46 have short flight times, the sector flight times do not fluctuate greatly among those flights. As a result the complexity and potential workload to handle these relatively uniform flights are greatly reduced, supporting the resulting increase in MAP.

To ensure the consistency of these findings, the analysis was expanded to all ZMA sectors and analyzed all 20 weeks for which we had data (February, July, October, November, and December 2015). MAP values were calculated for each week of this analysis and Table 9 presents the minimum, maximum and weighted average calculated MAP values from these 20 weeks of MAP calculations.

Table 9. Calculated vs Published MAP Statistics

Sector	Min calc MAP	Max calc MAP	Avg calc MAP	Pub MAP	Diff Pub-Avg
1	13.1	15.4	14.1	18	3.9
3	16.6	18	17.9	10	-7.9
6	17.3	18	17.9	15	-2.9
7	11.2	13.1	12.5	13	0.5
18	18	18	18	18	0.0
23	11.8	15	13.3	14	0.7
26	10.1	12.2	10.9	15	4.1
46	9.77	10.7	10.3	15	4.7
66	18	18	18	15	-3.0

Three categories can be distinguished in Table 9. Sectors 1, 26, and 46 have published MAP values higher than their average calculated MAP. It seems that for these sectors the calculated MAP has underestimated the capacity and ZMA has increased the MAP based on experience.

In Sectors 7, 18, and 23 the difference between the calculated and published MAP is minimal which could indicate that the calculation yielded a reasonable measure of capacity that matched the complexity of operations and the Center did not need to alter those values.

Finally, in Sectors 3, 6, and 66 the calculated MAP value appears to have overestimated the capacity. It is assumed then that ZMA has lowered these MAP values to represent the lower capacity due to higher complexity of operations in those sectors.

The preceding analysis of averages (current guidance) and variability is based on verifying existing MAP values with current flight traffic patterns and flight times. From this analysis it appears that ZMA accounts for the fact that the baseline MAP calculation cannot take the complexity of the operations into account. Rather, ZMA has acted within policy to adjust MAP values to what their TM personnel believe to be appropriate levels based upon their experience.

Linking MAP to Performance

Clearly, MAP plays a critical role in identifying potential demand and capacity imbalances so that TM personnel can take appropriate actions when necessary. From a performance and efficiency standpoint, however, the extent to which MAP affects system performance must be analyzed. Ultimately, processes should be developed to determine the extent to which MAP values are constraining to the system and result in inefficiencies.

The logical flow of such a process follows:

(1) Inefficiency must be defined, identified and measured.

(2) The TM decisions that caused the inefficiency must then be identified.

(3) Finally, the root cause of the TM decision must be found.

If these three steps can be achieved, the excess distance flown by a specific flight due to a TMI issued to reduce flow through a specific sector that was alerted with a MAP exceedance will be quantifiable. At this time, the extent to which cases can be identified where MAP was the root cause of inefficiencies is limited due to data challenges.

Measuring Inefficiency and Linking to a TM Decisions

Archived Trajectory Data. The Office of Performance Analysis has experience in measuring multiple indicators of inefficiencies in the NAS. Included among these measures are excess distance flown and level flight flown during descent. These and other measures are computed using archived trajectory data from the TFMS and/or National Offload Program (NOP) systems. While many of these measure are mature and would accurately reflect the impact of decisions on system performance, there is not yet a way to link affected trajectories to TM decisions such as rerouting.

OPSNET. The OPSNET database captures minutes of delay in the system and attributes them to the facility that requested the TMI. However, it does not attribute delays below the center level, thus any ZMA sector causing a delay would be attributed to ZMA without the ability to drill down further. Additionally, it does not capture many inflight delays, nor does it capture a pre-flight re-route as a delay.

Linking TM Decisions to Root Causes

TFMS. While calculating historical sector loading is achievable through actual trajectory data, that information is only valuable when determining the effects of any TM decisions. If a sector exceeding MAP value is detected by processing the historical flight trajectories, that overage was likely mitigated and allowed to occur after the TFMS forecast identified it. As a result, historical flight trajectory data does not allow detection of the situation that caused a TMI or re-route. The forecasted sector loading, is viewed by TM personnel through the TFMS system. TFMS forecasts are not warehoused which may inhibit an analysis of conditions leading to TM decisions. However, replicating the TFMS forecast may be possible by using historical flight plan filing data.

National Traffic Management Log (NTML). The NTML database contains a table of MAP alerts. This table is being analyzed under a parallel effort within FAA's Office of Performance Analysis (AJR-G) and preliminary results are beginning to emerge. Figure 7 displays an apparent system change from 2015 to 2016 for red MAP alerts in ZFW as there is a significant trend upward when comparing January and February alerts for the two years.

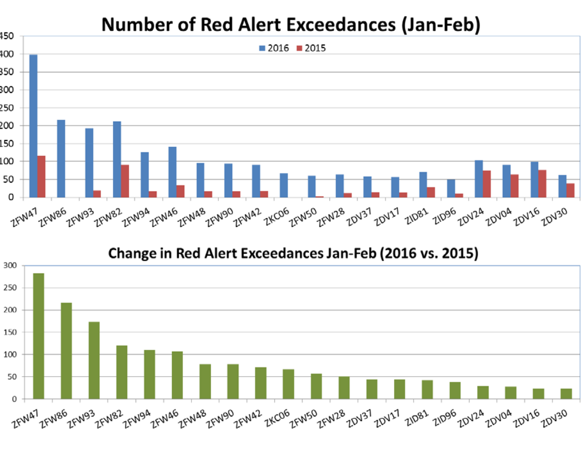

Figure 7.MAP Alert Year to Year Changes

Notice to Airmen (NOTAM) messages. Most of the re-routing decisions intended to relieve sector loading concerns are communicated through the NOTAM system. These messages identify the affected routes and direct those routes to new ones, but they do not attribute the reroute decision to a root cause. Additionally, parsing NOTAM messages for large scale analysis would present a challenge. Finally, many, and perhaps most, of the re-routes that are put in place are intended to relieve excess flow over an FCA. While this is effective at relieving the pressure at the affected airports and sectors, the constraining airport(s) or sector(s) are not specifically identified.

Conclusions

1. Sector Complexity. It is apparent that the baseline MAP calculation method is inadequate for some sectors due to the data constrained assumption that all aircraft require 36 seconds of controller time regardless of the complexity of the sector. There are some initial indications that analyzing the variability of the average flight times may give insight into these complexity issues.

2. Average flight times. The analysis has shown that the calculation of average sector times is not stable and can vary significantly depending upon the assumptions behind the calculations. Additionally, the sector flight times are highly variable and call into question the practice of setting a Sector's capacity indicator based upon this calculation alone.

3. ARTCC Adjustments. Our analysis leads us to believe that the TM personnel working the sectors have already recognized the shortfalls of MAP and made the appropriate adjustments. The FAA policy on MAP allows for this leeway. The leeway given in the policy implies that those writing it knew of the shortfall when it was written.

4. Known data sources provide an incomplete picture for analyzing the post-operational impacts of MAP and identifying sectors that act as constraints to the system.

Recommendations and Next Steps

1. Baseline MAP calculations. While it is clear that baseline MAP calculations can misrepresent the capacity of a Sector, the required adjustments seem to have been made at the ARTCC. Before investing in a new methodology for determining baseline MAP, the FAA should consider a cost/benefit analysis of the effort.

2. Dynamic adjustments and combining sectors. While not specifically analyzed, it appears a material shortfall of the current MAP implementation is the inability to adjust MAP dynamically due to changing conditions, including the combining or splitting of Sectors. This lack of capability forces TM personnel to make adjustments on the fly as the TFMS MAP alert function becomes irrelevant due to changed conditions. This apparent shortfall should be further analyzed with a potential focus on the relationship between the variance of sector flight times and the need for dynamic MAP adjustments

3. The requirements for a new OPSNET database are currently being written. That effort should consider the findings of this paper in order to potentially include data at the sector level. Future analysis will seek to link delay charged to airspace constraints in OPSNET to MAP exceedances recorded in NTML or events from other complementary databases.

4. The analysis should be expanded to ensure that ZMA was representative of the entire NAS. Additionally, future analysis should consider including the MAP alert data introduced in Figure 7 and attempt to find meaningful linkages between the data sets.

5. Additional research is needed to expand the analysis of using indicators of statistical variation of flight times as a trigger for calculating or adjusting baseline MAP values.

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