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A NEW APPROACH to Monitoring and Alerting Congestion in Airspace Sectors

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A New Approach to Monitoring and Alerting Congestion in Airspace Sectors

Rethinking the Alert System for 15-Minute Intervals

By Eugene Gilbo, Scott Smith, and Mike McKinney

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Abstract

The Federal Aviation Administration (FAA) Traffic Flow Management System (TFMS) currently declares an alert for any 15-minute interval in which the predicted demand exceeds the Monitor/Alert Parameter (MAP) for any airport, sector, or fix. For airports and fixes, traffic demand is measured by aggregate 15-minute counts. For a sector, however, TFMS predicts the demand for each minute, and then uses the demand of the peak minute in a 15-minute interval to decide whether to declare an alert for the entire 15-minute interval. Using the peak demand from a single minute to declare alerts has been criticized by TFM specialists for three reasons. First, the demand from a single minute does not accurately reflect the workload for the entire 15-minute interval. Second, using demand for a single minute leads to instability; that is, slight fluctuations in demand from minute to minute can lead to alerts flickering on and off. Third, the interval that is alerted depends on arbitrary 15-minute boundaries. To deal with the current method, we propose a new system of declaring sector alerts that is based on the patterns of one-minute demands that more closely mimics traffic managers' instincts for potential problems.

Introduction

This paper presents the latest results of research conducted at the Volpe Center supported by the FAA on enhancing the Traffic Flow Management System (TFMS) Monitor/Alert function for identifying potential congestion at National Airspace System (NAS). This research contributes to the FAA's effort to improve aviation safety and efficiency of utilizing the NAS operational resources while accommodating increased air traffic demand, which are among the major goals of

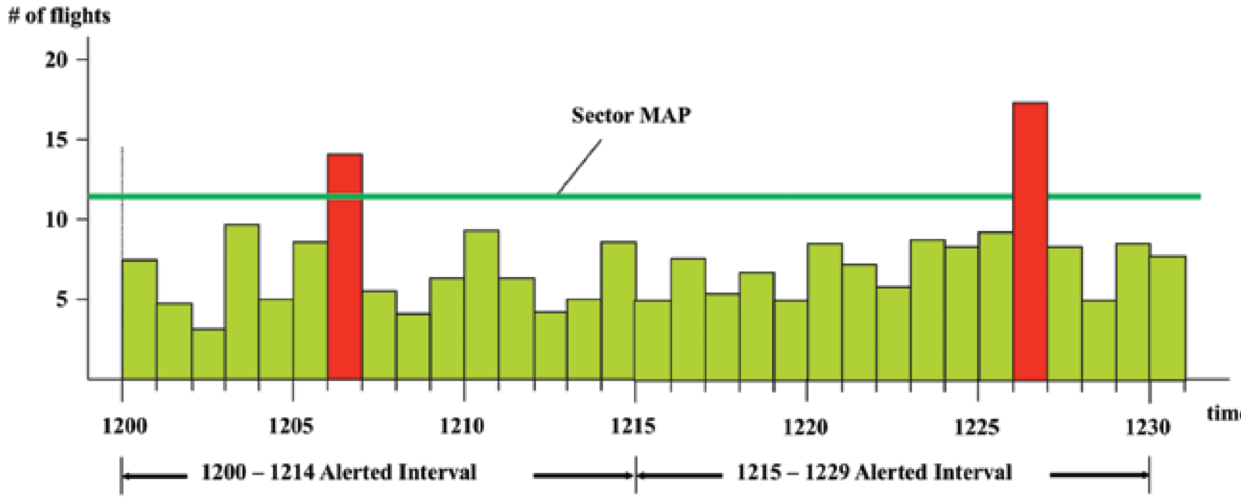

Figure 2.1. Example of current TFMS sector alert rule

the Next Generation Air Transportation program (NextGen)[1]. One of the means to increase aviation safety is improvement of strategic air Traffic Flow Management decision making, which requires more accurate and reliable predictions of congestion in the NAS. Exploring new methods for improving TFM decision-making is an important research component to support NextGen goals.

TFMS predicts the volume of air traffic for airports, sectors, and fixes to identify potential congestion problems. TFMS's Monitor/Alert functionality compares predicted traffic demand with available capacity or Monitor/Alert Parameter (MAP) and issues alerts wherever and whenever demand threatens to exceed capacity. This helps TFM specialists in their strategic decision-making for resolving congestion problems.

Although the general alerting rule is the same for airports, fixes, and en route sectors, and is based on comparison of predicted demand with available capacity, the TFMS defines traffic demand for sectors differently than for airports and fixes. Traffic demand for airports and fixes is measured by aggregate number of flight counts per 15-minute interval, e.g., number of arrivals or departures at an airport per 15-minute or number of flights crossing a fix per 15-minute. Those aggregate 15-minute demand counts are used in determining airport or fix alert status. For sectors, TFMS uses a different approach to determining sector demand and sector alert status.

Currently, TFMS uses the following algorithm to determine if a sector is alerted at a 15-minute interval.

- For each minute of the 15-minute interval, TFMS predicts the demand for that minute, i.e., the number of flights that will be in that sector during that minute.
- TFMS compares the demand for each minute with the MAP for that sector.
- If the demand for any one-minute exceeds the MAP, then the entire 15-minute interval containing that minute is alerted.

Stated another way, the maximum demand for any minute during a 15-minute interval is taken to be the demand for that interval; it is clear, however, that the peak one-minute aircraft count during a 15-minute interval may not adequately reflect the level of complexity of the traffic and sector workload for the entire 15 minutes.

The purpose of this paper is to propose a new method of defining sector alerts, which is based on patterns of one-minute demand predictions instead of peak one-minute demand counts. The idea of using demand patterns for determining sector congestion and for sector Monitor/Alert application was first presented in 2008 Volpe report[2]. Extensive statistical data analysis of new alerting algorithms was performed on 14 days' TFMS data collected at 31 sectors. The results of the analysis were presented in 2011 Volpe report[3]. The paper uses materials from these reports.

The paper is organized as follows:

- Section 1 discusses the problems with the current TFMS sector-alerting rule.
- Section 2 introduces one-minute sector demand patterns for identifying alert intervals in a sector.
- Section 3 introduces a concept of long-term and short-term alerts based on traffic demand patterns and explores an option of displaying those alerts in the TFMS sector Monitor/Alert display.

1) Problems with the Current Sector Definition of Alerts

The first problem with the current concept is that it does not track well with sector workload. If, for example, demand exceeds the threshold for only one minute in a 15-minute interval, with the demand for the other 14 minutes being below the MAP threshold, TFMS will alert the sector for the entire 15-minute interval regardless of the magnitude of the one-minute peak demand. Since the air traffic control (ATC) can typically deal with a problem so circumscribed, the traffic managers and controllers have to pay attention to the alert message and the magnitude of traffic demand even if it exceeds the MAP only in a single minute of the 15-minute interval. Moreover, the current TFMS does not distinguish a

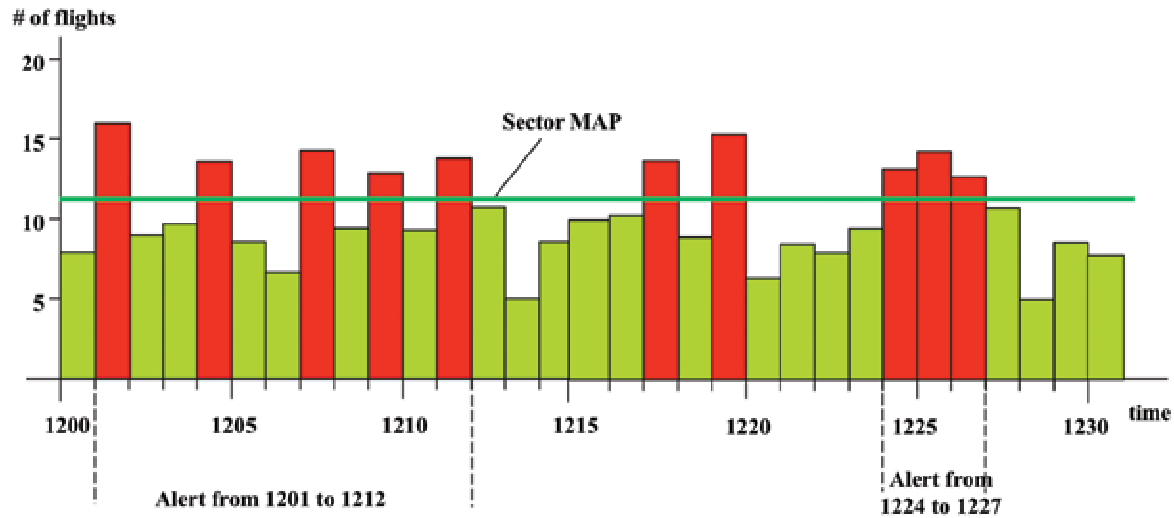

Figure 2.2. Example of patterns of demand that result in two alerted Intervals

short-term congestion problem that lasts for a couple of minutes from a long-term congestion that would significantly affect traffic manager workload.

A second problem with the current concept is that it is an unstable measure that leads to flickering of alerts. For example, it is often the case that, when the predicted one-minute peak demand is close to capacity, non-operationally significant small changes in demand (say, one or two flights) from one traffic update to the next will cause an alert to toggle either on or off. Since Monitor/Alert is updated every minute, these tiny changes in predicted demand can cause a sector's alert status to vibrate back and forth, pointlessly increasing workload for the traffic manager.

A third problem with the current concept is that it depends on arbitrary 15-minute timeline boundaries. While such intervals might make it easier to present bar graphs, they are not directly related to the traffic in the sky. A concept is desired that uses the pattern of demand to determine alert status unaffected by artificial boundaries in the timeline.

These problems, as well as the new concept proposed here, have arisen from discussions with TFM/ATC specialists from various FAA facilities, including ATCSCC, ARTCCs, TRACONs, and ATCTs. They have criticized the current TFMS method of alerting sectors for being an unrealistic measure of workload, for being overly sensitive, and for focusing on arbitrary 15-minute intervals.

2) Patterns of One-minute Demands vs. One-minute Peak Demand for Alerting Sectors

In a 2008 report [2], a new concept was first proposed on determining alert status at sectors based on the patterns of overloaded and non-overloaded (normal) one-minute sector demands. A more detailed analysis of application of the demand patterns can be found in a 2011 report [3]. The concept received a positive response from several TFM specialists. The patterns are defined by two parameters: the minimum number of overloaded minutes (not necessarily consecutive) sufficient for declaring a sector alert (the "on" parameter), and the minimum number of consecutive non-overloaded minutes sufficient to reset the alert (the "off" parameter).

Start with the current TFMS sector alert rule: a sector is alerted for a whole 15-minute interval if the peak one-minute demand count within the 15-minute interval exceeds a sector MAP.

Figure 2.1 illustrates the case when there is only one overloaded minute in each of two 15-minute intervals from 1200 to 1230. (Note: in this figure, for the sake of simplicity, red bars are used for predicted demands that exceed a MAP. The TFMS, however, shows active and proposed components of the demand using different colors for each component).

In this example, TFMS would alert both 15-minute intervals, i.e., it would alert the entire 30-minute time period.

Figure 2.1 also illustrates the potential instability and inaccuracy of a sector alert. The excess demand for the 12:06-minute does not appear significant, and, due to random prediction errors, the next traffic demand update could be below MAP for the 12:06 minute. If the other updated minutes in the first 15-minute interval remain normal, the entire 12:00 – 12:15 interval would not be alerted by TFMS. The next update, however, could return the 12:00 – 12:15 interval back to alerted status.

This simple example illustrates the potential problems with the current TFMS sector Monitor/Alert algorithm concerning workload, instability, and arbitrariness that were mentioned earlier in this paper.

Here, we introduce demand patterns that can be used for identifying sector congestion and triggering alerts.

A demand pattern is a combination of one-minute intervals where traffic demands exceed sector MAP in some or all of the intervals. Any minute for which the predicted demand exceeds the MAP is called an overloaded minute. Otherwise a minute will be called a non-overloaded or a normal minute. Hence, the sector demand pattern is a combination of overloaded and normal minutes.

To identify a sector alert, two parameters of demand patterns are introduced:

- Parameter ***a*** that determines a minimum number of overloaded

Continued on page 32

All illustrations courtesy of Eugene Gilbo

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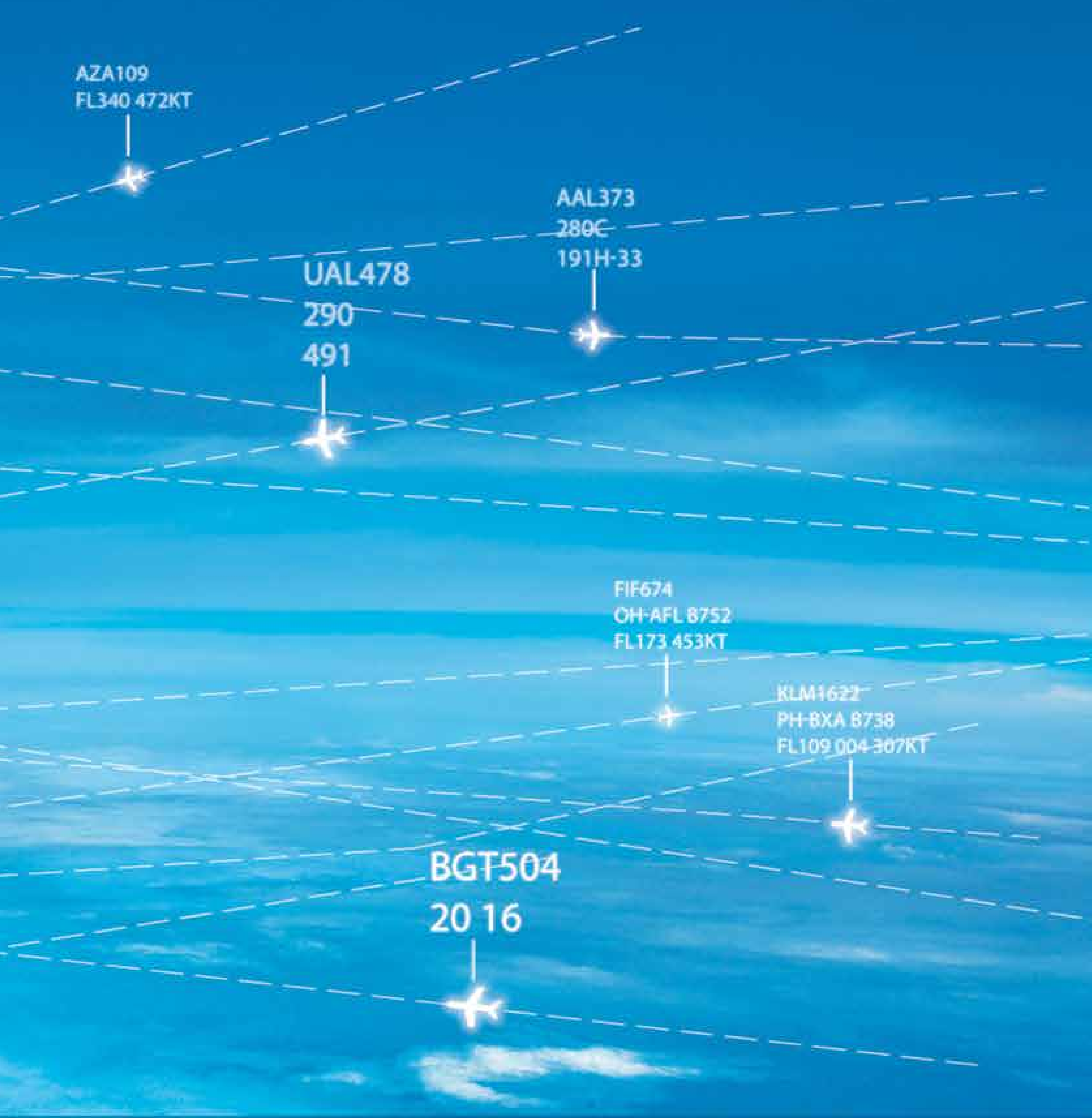
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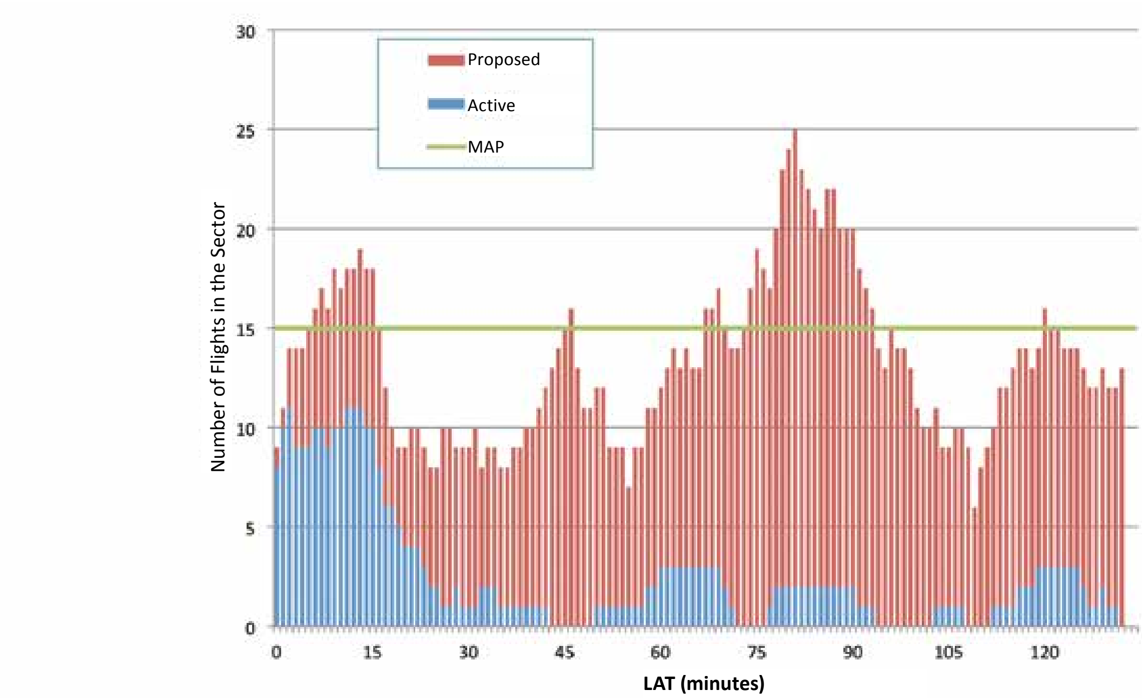

Figure 2.3. Predicted traffic demand

minutes (not necessarily consecutive) sufficient for declaring an alert

- Parameter ***b*** that indicates a minimum number of consecutive normal minutes between two overloaded minutes required to "reset" an alert, i.e., whenever b or more consecutive normal minutes are encountered, the counting for identification of next alerted interval will be restarted at the end of the string of normal minutes. This parameter characterizes a density of overloaded minutes necessary for declaring alerts and helps determine the start and the end of an alerted interval.

In other words, ***a*** or more overloaded minutes turn alert on, and ***b*** or more consecutive non-overloaded (normal) minutes turn alert off.

To illustrate how these alerting rules would work, consider the example pictured in Figure 2.2. This figure shows predicted sector demand at each minute of the 31-minute period that starts at 12:00 and runs through 12:30. Assume ***a*** equals three and ***b*** equals three. This means that a sector alert is declared for any interval with at least three overloaded minutes and with fewer than three consecutive normal minutes.

In Figure 2.2, the checking for sector alert starts from the first overloaded 12:01-minute. Just after 12:01, there are two consecutive normal minutes followed by one overloaded 12:04-minute. (So far, we have two overloaded minutes separated by less than three consecutive normal minutes, so that we can continue count). The next overloaded 12:07-minute is also separated from the previous overloaded 12:04-minute by less than three consecutive normal minutes. Thus, there are three overloaded minutes, close to each other, which is enough for declaring a sector alert that starts at 12:01. We need to continue counting overloaded and normal minutes to find the end time for sector alert. Figure 2.2 shows that the three subsequent overloaded minutes are separated by less than three (actually by one) normal minutes, and the 12:11-overloaded minute is followed by five (more than three) normal minutes. Hence, the alerted interval starts at 12:01 and ends at 12:12. The search for a candidate alert interval should then be restarted until encountering to the first overloaded 12:17-minute. The next overloaded 12:19-minute is separated from the 12:17-overloaded minute by one normal minute so that there are two closely separated overloaded minutes, and this is not enough so far for alerting a sector. After the 12:19-overloaded minute, there are four normal minutes. It means that interval 12:17–12:20, containing only two overloaded minutes, cannot be alerted, and the search for alerted interval should restart and continue. The next alerted interval is 12:24–12:27, because it contains three consecutive overloaded minutes followed by four normal minutes.

It is worth noting that in the pictured interval there are two alerted intervals lasting three and 11 minutes for a total of 14 alerted minutes; in contrast, TFMS currently would alert two consecutive 15-minute intervals, i.e., it would alert for 30 minutes from 12:00 to 12:30.

This example illustrates that looking not at a single minute but at the pattern of demand over time holds out the possibility of dealing with the problems with the current TFMS concept that were discussed in the Introduction. First, since three consecutive minutes of demand are more likely to represent a true traffic management problem than one minute, this pattern is less likely to flag harmless situations as an alert. Second, since this pattern does not allow an alert to be declared because one minute happens to have demand greater than capacity, this improves stability. Third, it doesn't matter if two of these three minutes are the last two minutes in one 15-minute interval,

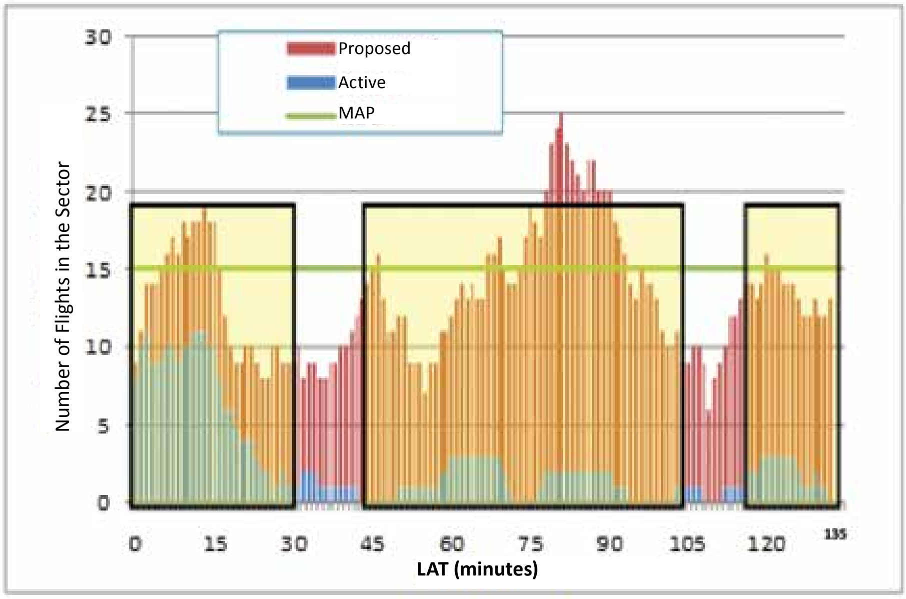

Figure 2.4. Sector Alert periods identified by current TFMS
In this figure, the yellow rectangles are overlaid onto the chart from Figure 2.3

and the last of the three minutes is in the next 15-minute interval since the boundaries of the 15-minute intervals are ignored.

Below, we will present some examples based on TFMS sector demand data to illustrate how demand patterns affect the alerted intervals.

For identification of demand patterns, the following notation will be used: ***a*** on, ***b*** off. It means that ***a*** or more overloaded minutes turn alert on, and ***b*** or more consecutive non-overloaded minutes turn alert off.

Figure 2.3, which is taken from actual minute-by-minute predictions, shows traffic demand predicted for each one-minute interval of a two hours and 15 minute (or 135min) period in a sector with the sector MAP equals 15. The boundary of the first 15-minute interval starts at LAT = 0 (LAT stands for look-ahead time. This refers to how far in the future a prediction is being made). Each bar in the figure shows active and proposed fractions of one-minute demands by different colors.

In Figure 2.3, there are several overloaded minutes, where one-minute demands exceed the sector MAP.

Of nine 15-minute intervals comprising the 135-minute period, current TFMS Monitor/Alert would alert all but two 15-minute intervals, because most of the intervals have at least one overloaded minute. Figure 2.4 highlights the alerted intervals.

Subsequent illustrations will focus on a 60-minute fraction of sector demand predictions with LAT between 45 and 105, which represents the large central peak in Figures 2.3 and 2.4.

The "three on, three off" sector-alerting rule, applied to this demand, is shown in Figure 2.5.

In Figure 2.5, the first alerted period lasts only three minutes from the 67th to the 69th minutes (see yellow highlighted area), and the second alerted period lasts 20 minutes from the 74th to the 93rd minutes. The total number of alerted minutes in those two intervals is equal to 23. (Recall that in current TFMS, the entire 60-minute interval in Figure 2.4 is alerted.) In Figure 2.5 the alert periods fell into the time periods where the vast majority of one-minute sector demands exceeded the sector MAP, while the single overloaded minute at LAT=46 substantially separated from the next overloaded interval by normal minutes was ignored by the rule for alerting the sector.

The next example, shown on Figure 2.6, illustrates the "three on, five off" alerting pattern. In comparison with the "three on, three off" pattern, this one increased the number of consecutive normal minutes sufficient for resetting alerts from three to five minutes. As a result, the two alerted periods from Figure 2.5 were merged into a single and longer alerted period of 27 minutes.

Consider another alerting pattern "five on, three off", in which, in comparison with the previous example of "three on, three off", the number of overloaded minutes sufficient for triggering an alert increased from three to five. Figure 2.7 shows that this pattern provided a single alerted period of 20 minutes. The increase of "on" parameter from three to five in the alerting pattern, while having the same "off" parameter, reduced the duration of alerted period from 23 to 20 minutes.

If we increase the "off" parameter from three to five, and apply the "five on, five off" pattern to the same demand (see Figure 2.8), the alerting period is the same as the one in Figure 2.7. In other words, in this example, increasing the number of consecutive normal minutes sufficient for resetting alerts with the same "on" minutes in the pattern did not change the duration of alert. It happened because of the demand profile in this specific example.

The examples illustrate some tendencies in changing alerted intervals caused by varying parameters of demand patterns for alerting sectors. Intuitively, it is expected that increasing the minimum number of overload-

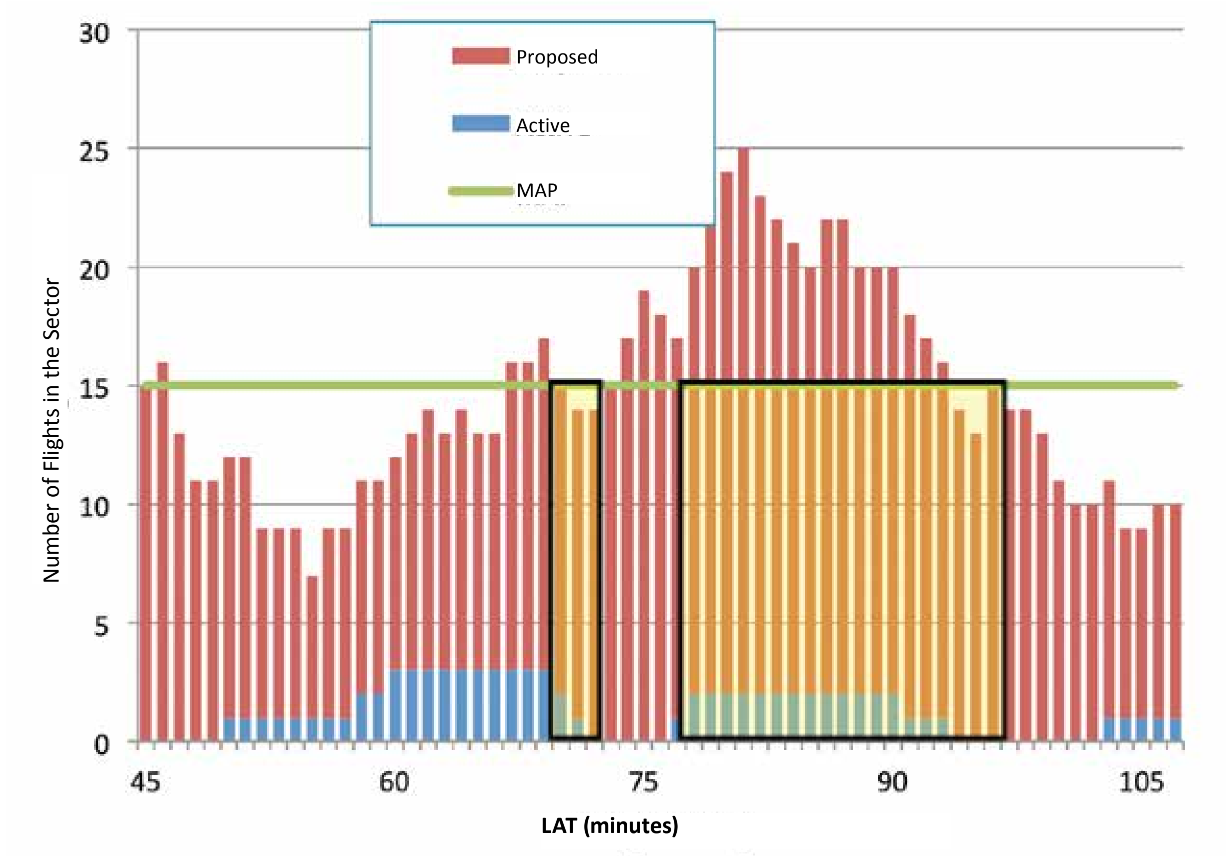

Figure 2.5. Sector alert periods identified by the "three on, three off" alerting rule

ed minutes sufficient for triggering an alert (parameter ***a***) would make it harder (at least not easier) to trigger alerts, and, hence, could cause the reduction in alerted periods. It is also expected that increasing the minimum number of consecutive normal minutes sufficient for resetting alerts (parameter ***b***) would make it harder (at least not easier) to end an alert and hence would result in increasing (or, at least, not decreasing) periods of alerts. It is also clear that alerted periods identified by the patterns depend on the actual profiles of predicted sector demand. Therefore in order to extract some general tendencies in how parameters of the patterns affect sector alert periods, we performed statistical analysis based on much larger sets of TFMS traffic demand data than the sets used in this Section for illustrative purposes only. The detailed results of this analysis are presented in the Volpe 2011 report [3].

Some main results from the report[3] are shown below.

Historical TFMS data were used to illustrate various patterns of one-minute demand that can be considered for sector alerts and how the pattern's parameters affect the temporal characteristics of sector alerts.

The following patterns of one-minute sector demand were considered:

- (Three on, three off); (three on, five off); (three on, eight off);
- (Five on, five off); (five on, five off); (five on eight off);
- (Eight on, three off); (eight on, five off); (eight on, eight off).

The summary of statistical analyses of various demand patterns applied to alerting potential congestion in en route sectors are presented in Table 2.1. The analyzed data were collected from TFMS for:

- 16 sectors on April 28, 2010 , with a total of 24,480 sector-minutes observed
- 14 sectors on April 29, 2010 , with a total of 4,920 sector-minutes observed
- 11 sectors for several days in April 2009, with a total of 781,080 sector-minutes observed. Table 2.1 makes it possible to compare various alerting rules with current TFMS and with each other in terms of both the number of alerted minutes (duration) and the number of alerted periods.

The titles of the columns in this table are as follows:

- "TFMS alert rules" corresponds to the results obtained under sector alerting rule in current TFMS. Since the current measure provides alerts in 15-minute blocks, the number of alerted minutes is a multiple of 15.
- "Three on, three off" through "eight on, eight off" indicate demand patterns used for alerting sectors. The results of analysis of the total duration of alerts under various demand patterns, presented in Table 2.1, show that
- Demand patterns, applied for alerting sectors, significantly reduced the total duration of sector alerts in comparison with the current TFMS Monitor/Alert. For example, the TFMS Monitor/Alert identified 17,610 minutes of total alert whereas the demand patterns provided total alerted periods ranging from 2,508 to 4,009 minutes,

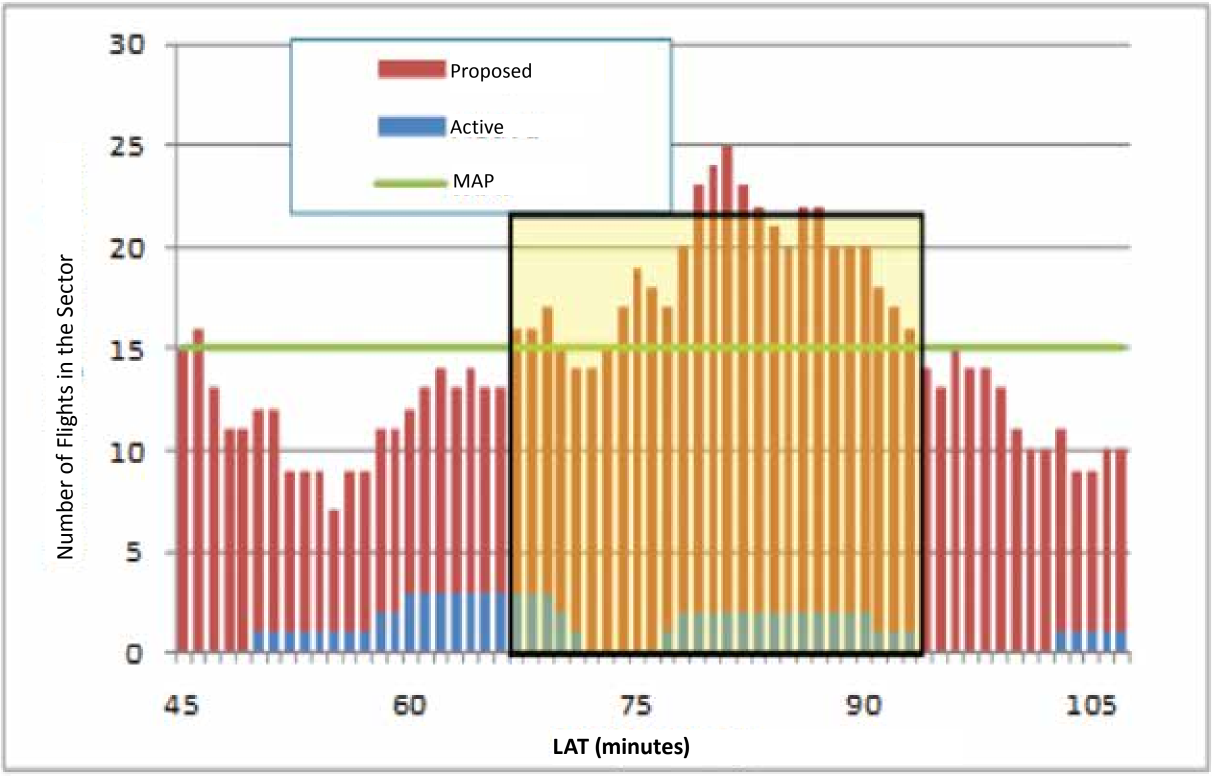

Figure 2.6. Sector alert period identified by the "three on, five off" alerting rule

which are between 4.4 and seven times shorter than under current TFMS Monitor/Alert.

- Total duration of alerts significantly depends on demand patterns and there are clear trends in the relationship between duration of alerted periods and parameters of demand patterns
  - Total duration of alerts increases with increasing "off" parameter under the same "on" parameter. For example, with increasing "off" parameter from three to five and eight under "on" parameter equal to three, the duration of alerts increases from 4,007 to 4,232 and 4,496, respectively.
  - Total duration of alerts decreases with increasing "on" parameter under the same "off" parameter. For example, with increasing "on" parameter from three to five and eight under the same "off" parameter equal to five, the duration of alerts decreases from 4,232 to 3,316 and 2,261 minutes, respectively.

Figure 2.9 gives a graphical representation of the "Total alerted minutes" row of Table 2.1.

Table 2.1 and Figure 2.9 show a clear relationship between the "on" and "off" parameters and the number of alerted minutes:

- As the "on" parameter increases, it becomes harder to turn alerts on because this increases the minimum number of overloaded minutes needed to trigger an alert. The downward slopes of the lines of Figure 2.9 illustrate this trend. Each line corresponds to a single "off" parameter, and shows the change in the total alerted minutes as the "on" parameter increases.
- As the "off" parameter increases, it becomes harder to turn alerts off. As a result, total alerted periods would become longer with a higher "off" parameter. The locations of the three lines in Figure 2.9, which correspond to the three "off" parameters, illustrate this trend.

The total number of alerted periods under various demand patterns, presented in Table 2.1, shows that using demand patterns for sector alert identification significantly reduced the number of alerts in comparison with the current TFMS Monitor/Alert. However, the relationship between parameters of demand patterns and the number of alerts is different versus total duration of alerts: the "on" parameter makes a big difference (fewer alerts with a higher "on" parameter), but, under the same "on" parameter, the "off" parameter makes no significant difference. Figure 2.10 illustrates this effect as the three lines in the figure practically lie on top of each other.

Finally, the third row of Table 2.1 shows an average number of minutes per alert. Again, demand patterns significantly reduced the average duration of alerts in comparison with the current TFMS Monitor/Alert. For example, the average duration of TFMS alert is 22 minutes per alert whereas the demand patterns provided average duration of alerts ranging from eight to 18 minutes per alert, which are between 18 percent and 64 percent shorter than TFMS alerts. It is worth noting that, similar to

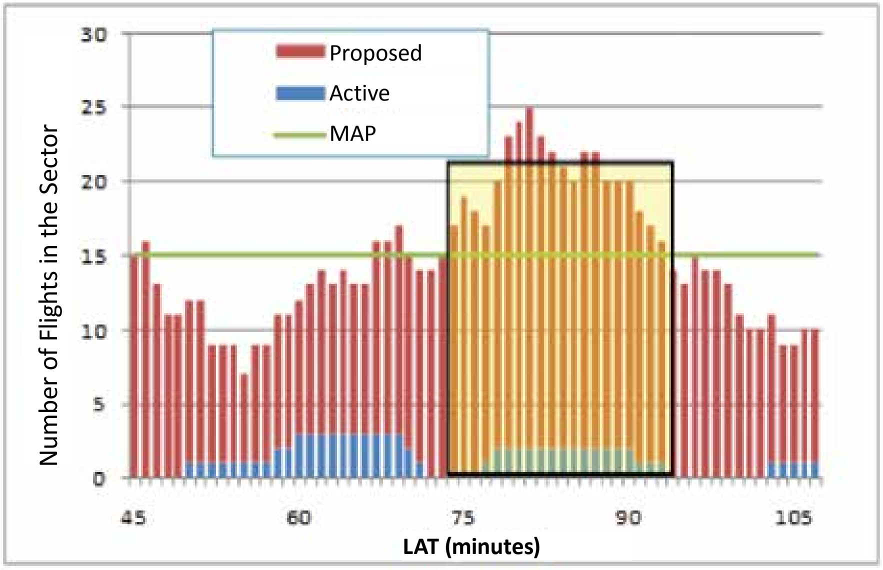

Figure 2.7. Sector alert period identified by the "five on, three off" alerting rule
In this figure, the yellow rectangles are overlaid onto the chart from Figure 2.5

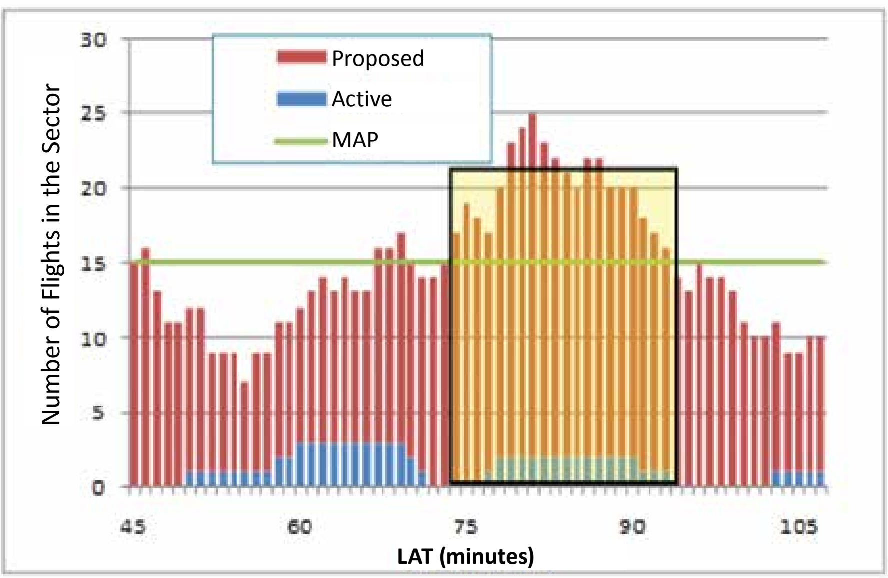

Figure 2.8. Sector alert period identified by the "five on, five off" alerting rule
In this figure, the yellow rectangles are overlaid onto the chart from Figure 2.5

the number of alerts, the change of "on" parameter has greater impact on average duration of alert than the change of "off" parameter under the same value of "on" parameter. Table 2.1 also illustrates that higher parameters of demand patterns result in longer alerts.

3) Long-term and Short-term Alerts

The presented approach offers an alternative for improving TFMS Monitor/Alert functionality in predicting potential congestion at sectors: a sector is alerted during a time interval when the combination of overloaded and normal minutes within the interval meets the alerting criterion in accordance with parameters of demand patterns selected for identifying sector alert (the number of overloaded minutes should be at least ***a*** minutes and the number of consecutive normal minutes between two closest overloaded minutes should be less than ***b*** minutes). It is a clear rule for detecting significant congestion and its duration that would require a serious attention of TFM specialists. An extreme example of this rule is that a single overloaded minute surrounded by a certain amount of normal minutes would not create an alert. However, the TFM specialists must pay attention even to a single overloaded minute (and current TFMS alerts the whole 15-minute interval even when there is only a single overloaded minute within the interval). This fact makes it necessary to expand the proposed demand pattern approach for alerting sectors. The sector alerting rule based on demand patterns addresses more or less prolonged time interval with a dense concentration of overloaded minutes. The question is, how to notify TFM specialists to intervals that contain overloaded minutes but were not alerted because of the values of parameters in demand patterns. Definitely, such periods have a smaller number of overloaded minutes. That's why, we will call these alerts as "short-term alerts" with smaller numbers of overloaded minutes (smaller than parameter a in demand pattern) as opposed to "long-term alerts" with the higher number of overloaded minutes.

Figure 2.2 illustrates long-term alerts in the case of demand patterns with parameters ***a*** and ***b*** equaling three. In this figure, there is an interval between 1217 and 1219 with two overloaded minutes, which was not alerted because it contains less than ***a*** equals three overloaded minutes and was surrounded by more than ***b*** equals three normal minutes. This interval represents a short-term alert.

In the TFMS Monitor/Alert display, short-term alerted intervals should be colored differently than long-term alerted intervals to indicate the severity of congestion to TFM specialists. For illustration only, we will use red color for long-term alert and pink color for short-term alert. Figure 3.1 reproduces Figure 2.2 and shows both long- and short-term alerts for demand patterns with parameters ***a*** and ***b*** both equaling three. In the figure, the longer of two long-term alert periods lasts for 11 minutes. The figure also illustrates a possible, but not a typical special case when a long- and short-term alert have the same duration of three minutes. The difference is that the long-term alerted interval, according to demand pattern, has three overloaded minutes, while the short-term alerted interval has only two overloaded minutes, i.e., less than ***a*** equals three minutes and less than ***b*** equals three normal minutes between them, and there are enough normal minutes between the alerted intervals to reset alerts.

As the new concepts of long- and short-term alerts are introduced, this leads to the question: What is the minimum and maximum possible duration of each of those alerts?

There is a straightforward answer concerning long-term alerts. The minimum possible duration of a long-term alert is a minutes, when there is no normal minutes between a overloaded minutes. There is no limit for maximum duration of a long-term alert.

As for short-term alerts, only the minimum possible duration can be immediately found: it is one minute. It is not difficult, however, to show that the maximum duration of a short-term alert T_{max} is equal to $T_{max} = (a - 1) + (a - 2)*(b - 1)$. For example, in the case of a = 3 and b = 3, with maximum two overloaded minutes (a – 1 = 2) and with maximum two normal minutes between two consecutive overloaded minutes (b – 1 = 2) necessary for short-term alert, the maximum duration of the short-term alert is equal to $T_{max} = (a - 1) + (a - 2)*(b - 1) = 2 + 1 * 2 = 4$ minutes..

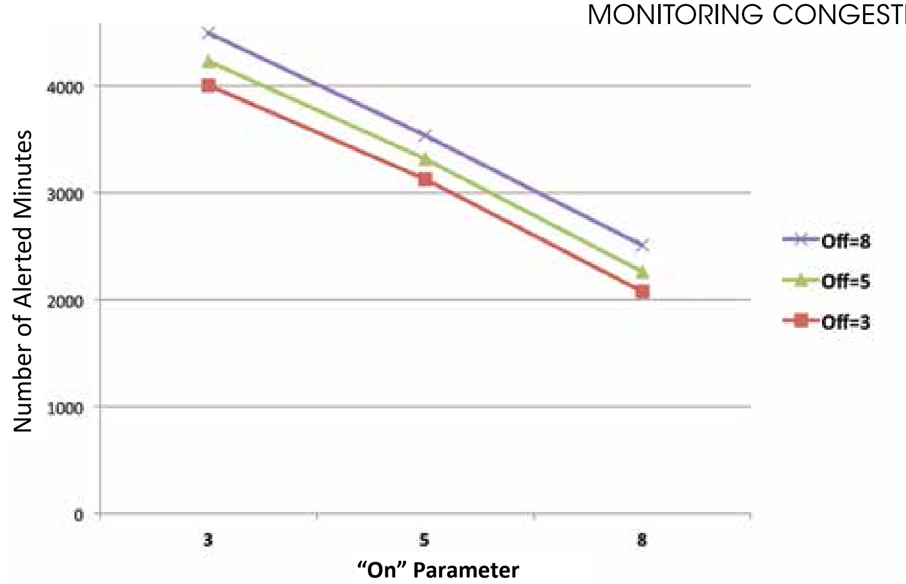

Figure 2.9. Total number of alerted minutes for various demand patterns

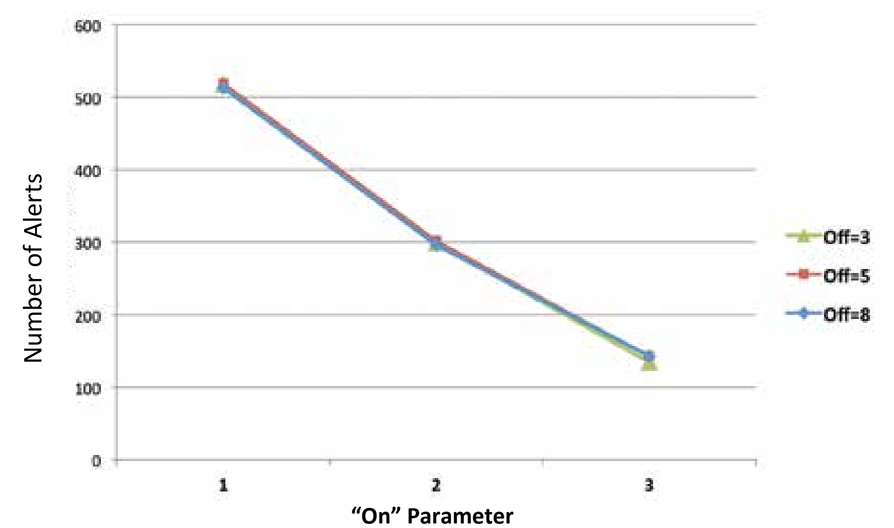

Figure 2.10. Total number of alerts for various demand patterns

3.1) Sector Alert Algorithm

Here is the algorithm for alerting sectors based on traffic demand patterns that covers both short- and long-term alerts:

1. Starting at any minute, look through the minutes, one at a time.
2. Find the first overloaded minute where demand exceeds MAP and accumulate a count of overloaded minutes along with the counts of consecutive normal minutes separating two adjacent overloaded minutes.
3. When consecutive ***b*** normal minutes are encountered, check the total number of overloaded minutes, including the last one that is followed by the ***b*** normal minutes.
4. If the total number of overloaded minutes is equal or greater than ***a*** minutes, then a long-term alert is declared that begins with the first of these overloaded minutes and extends to the last overloaded minute that is followed by ***b*** normal minutes. Then restart the counts from step two.
5. If the total number of overloaded minutes is less than ***a*** minutes, then a short-term alert is declared

Table 2.1. Summary alert characteristics under various demand patterns

Alert characteristics	TFMS alert rules	Demand patterns								
		3 on 3 off	3 on 5 off	3 on 8 off	3 on 3 off	3 on 5 off	3 on 8 off	3 on 3 off	3 on 5 off	3 on 8 off
Total alerted minutes	17610	4007	4232	4496	3126	3316	3537	2075	2261	2508
Total number of alerts	783	518	519	513	299	302	296	135	143	143
Average minutes per alert	22	8	8	9	10	11	12	15	16	18

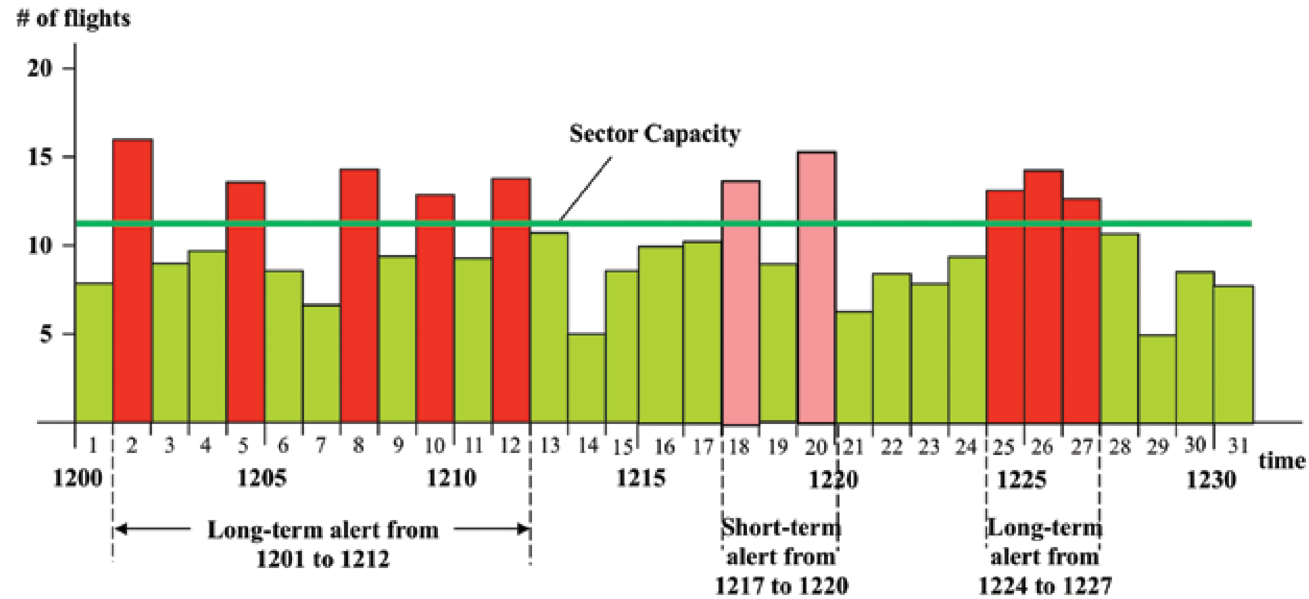

Figure 3.1. Example of patterns of demand that result in long-term and short-term sector alerts

for the whole interval that includes the first and the last overloaded minutes. Then restart the counts from step two.

3.2) An Option for Displaying Sector Alerts on TFMS Monitor/Alert

This paper focuses only on the new concepts and will not go in depth into user interface issues such as whether long-term and short-term alerts should be displayed differently. Nevertheless, we will try to use an option of coloring short- and long-term alerts that was discussed above in this paper for displaying those alerts in the TFMS Monitor/Alert.

This section offers some preliminary ideas for modifying the existing TFMS user interface to show long- and short-term alerts. The idea is to use the existing TFMS user interface with the existing timeline that shows 15-minute intervals, and to color the new alert intervals regardless of the locations of the 15-minute boundaries: long-term alerts in red or yellow (depending on the status of the flights) and short-term alerts in pink (or some other color). The alert intervals might be within existing 15-minute intervals, or might overlap portions of adjacent intervals.

Figures 3.2 and 3.3 use demand patterns from Figures 2.1 and 3.1 to illustrate the idea of possibly displaying both types of alerts in TFMS Monitor/Alert. In both cases, current TFMS would alert entire 30-minute period (see bottom left version in the figures), while, with demand pattern alerting rules, only fractions of 15-minute intervals would be alerted in different colors (see bottom right version), so that a TFM specialists would be aware of duration of potential alerts and use this information for his/her TFM decision-making.

Another example, shown in Figure 3.4, considers sector demand predictions for 2.5 hours from 1200 to 1430. The figure shows intervals of long- and short-term alerts using the alerting rule based on demand patterns with parameter a equal to three and b equal to four. The current TFMS alerting rule would alert the whole 2.5-hour period, as shown on the bottom of the figure. The new rules for establishing alerts would result in a significantly different pattern of alerts. The figure illustrates some key points of using demand patterns. First, for a TFM specialist the alert situation is not that stressful as in current TFMS display. Second, as alerting pattern ignore the boundaries of 15-minute intervals, two overloaded minutes at the beginning of 1215-1230 interval were included in alerting interval from 1204 to1217 and did not cause the alert for entire 15-minute interval from 1215 to 1230 while current TFMS alerted this whole 15-minute interval. Same effect took place when overloaded minutes were on both sides of 1245 time. As a result, unlike TFMS display, there were not serious overloads during some long intervals, e.g., from 1217 to 1248 and from 1320 to 1406.

The above examples illustrated a rough idea of displaying alerts based on demand patterns. If the concept of long- and short-term alerts is endorsed as a practical way for improving TFMS Monitor/Alert functionality and TFM decision making, an additional research effort would be needed for designing a new Monitor/Alert user interface. The research would require close collaboration with TFM/ATC specialists.

Conclusion

The basic idea of this paper is to base a sector alert on a pattern of minute-by-minute demand rather than on the demand for a single minute only. The proposed sector alerting rules reflect suggestions from TFM specialists. The proposed approach holds out the promise of being superior to the current approach used in TFMS for identifying sector congestion and its severity.

In particular, there are several advantages of using new rules for sector alerts based on a pattern of minute-by-minute demand vs. current TFMS rule:

1. The new alerting rules, based on traffic demand patterns, better reflect the practice of TFM/ATC specialists in evaluation and perception of sector alert status.
2. A new concept of long-term and

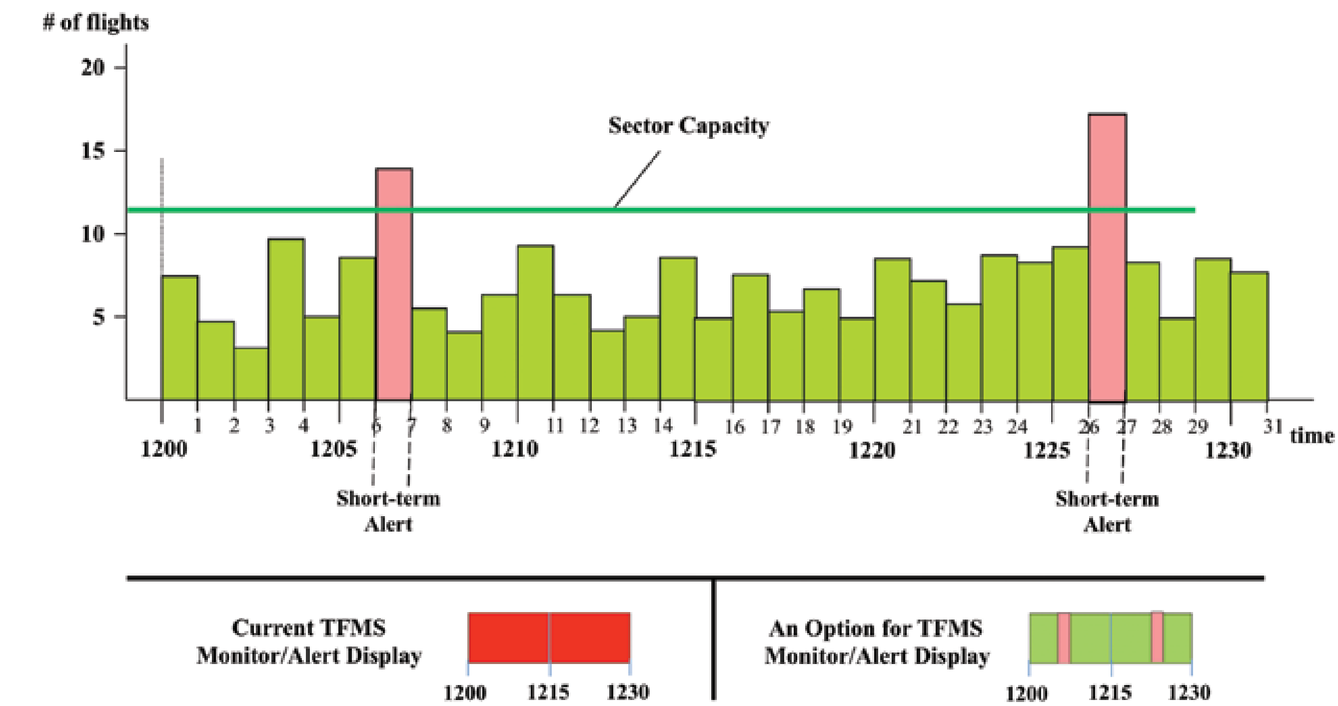

Figure 3.2. Example of displaying short-term alerts (bottom right version)

short-term alerts would give TFM specialists additional factors for consideration in their traffic management decision making process.

3. New rules are more flexible: they have two parameters of demand patterns that could be adjusted to detect real traffic management problems, to reflect complexity of particular sectors and traffic patterns within the sectors.
4. New rules would likely improve the stability of monitor/alert and reduce flickering due to taking into account the patterns of traffic demand for several one-minute intervals rather than for just one interval.
5. The new rules ignore the artificial boundaries of 15-minute intervals: the alerted intervals are not attributed to specific 15-minute intervals and can start and end at any time in accordance with alerting rules.

Further research would be needed to answer the following questions:

1. Is the concept of a long-term alert as defined above a valid concept that should be operationally deployed? If so, this leads to additional questions.
   a. What values should be chosen for the parameters ***a*** and ***b***?
   b. Should the parameters have the same value for every sector in the NAS? Or should each Center be allowed to set the parameters so that they are the same for every sector in the Center? Or should the system allow the parameters to be set differently for every sector, just as MAP values are currently set separately for every sector?
2. If long- and/or short-term alerts are deployed, what should the user interface look like?
   a. Currently, the map display of the TSD indicates alerted sectors with red and yellow polygons with different fill patterns.

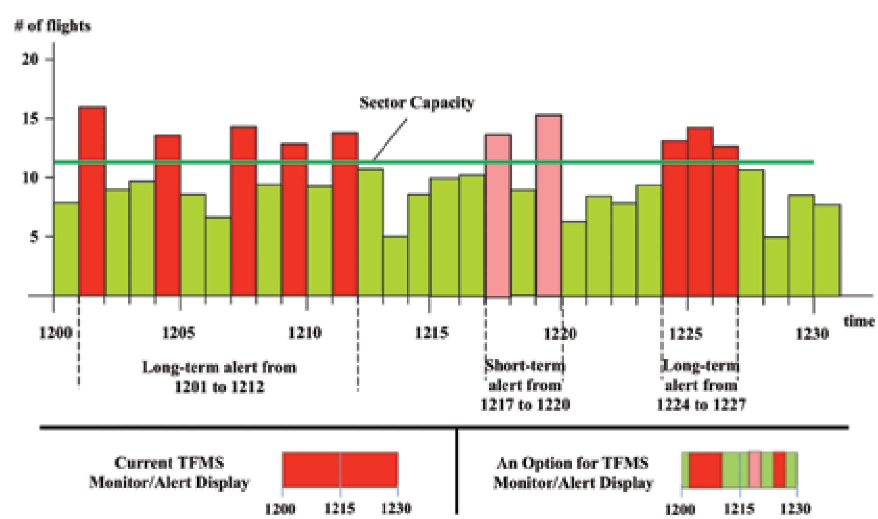

Figure 3.3. Example of displaying long-term and short-term alerts (bottom right version)

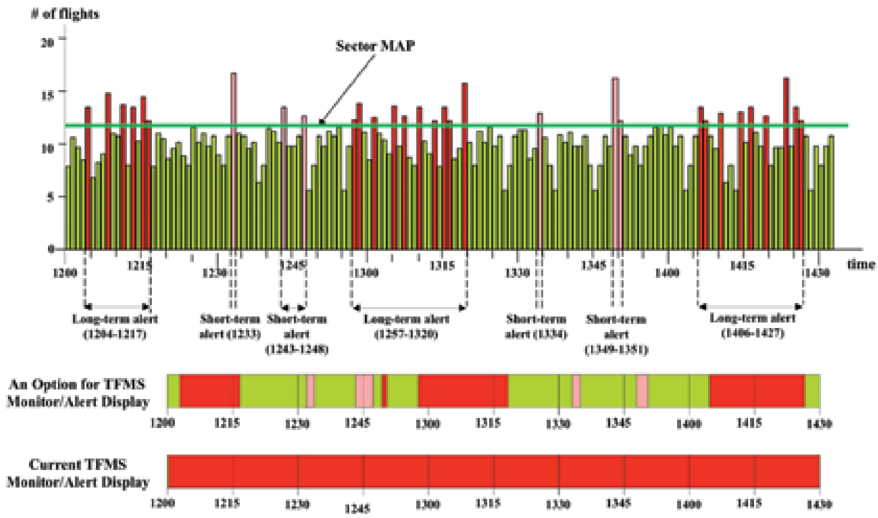

Figure 3.4. Example of displaying long and short-term alerts

Should this be changed so that long-term and short-term alerts are displayed differently?

b. How should long-term and short-term alerts be displayed in the NAS Monitor? Should this display distinguish long-term alerts from short-term alerts?

c. Should there be a new minute-by-minute display similar to the figures shown in this paper?

d. Should the user be allowed to toggle between the new approach and the current TFMS approach?

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