A Quick Cluster Control Method: Permanent Control Station Cluster Analysis in Average Daily Traffic Calculations

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A foundational piece of information in highway planning is average daily traffic (ADT). The way in which permanent control counters are used to adjust short-term traffic counts to ADT impacts current and forecast traffic analysis. ADT values affect geometric design of roadways. Too-low adjustment and forecast of ADT values can result in inadequate lanes or thickness of lanes, causing low levels of service and surface failure. Too-high ADT values can result in overbuilding a facility. The New Mexico State Highway Department has implemented a statistical procedure to improve the accuracy of ADT values. Whereas the previous procedure was to use a nearby permanent control counter to adjust short-term counts to ADT, the new procedure uses cluster analysis of permanent control counters. The clustering is based on functional classification of roadways. The benefit of cluster analysis has typically been a 3 to 4 percent per year improvement in ADT accuracy, resulting in 15 5o 20 percent accuracy improvement between traffic count years. When forecast to design year for a roadway, the method can improve volume accuracy by more than a lane of traffic. The quick cluster control method provides significant improvement in traffic accuracy without additional staff requirements.

Highway planning agencies attempt to use the best possible methodology at the lowest cost. This policy is particularly true in a period of budgetary constraint. To be acceptable, new methodologies must be demonstrated as providing significant improvement in accuracy, and must be implemented with current or reduced personnel. In this paper, a procedure to facilitate decision making in one area of improved highway planning methodology is outlined. The procedure, referred to as quick cluster control, demonstrates the accuracy and facilitates implementation of cluster analysis in traffic volume estimation.

One of the foundational pieces of information in highway planning is average daily traffic (ADT). ADT is an estimation of the daily traffic volume on a given roadway. Where there is a permanent counter, an hourly record of traffic is recorded for each day of the year. The daily totals may be summed, then divided by 365, to obtain annual average daily traffic (AADT). Where there is no permanent counter, short-term coverage counts for an area are conducted. Generally, there is a cycle of months or years between counts. The short-term count is taken over a period of days. A permanent counter is used to adjust the short-term count to an estimated ADT. In part, the accuracy of an ADT is affected both by the accuracy of the short-term count and by the factor used to adjust the count to ADT. A historical record of ADTs is maintained and updated annually.

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Why is the accuracy of ADT important? The ADT values for a roadway affect current and planned traffic control devices. The historical trend in ADT values is used to forecast traffic volume to roadway design year. Error in current ADT expands significantly as the data are forecast to the design year. Forecast volumes affect decisions on the usefulness of alternative relief routes and on the geometric design of relief routes. Forecast ADT based on annual record entries is also an essential portion of average daily load (ADL) values, which affect structural characteristics. Inaccuracy of ADT, current and forecast, can result in inadequate lanes or thickness of the lanes, causing low levels of service and surface failure. Too-high estimates of ADT can result in overbuilding a facility. In either circumstance, ADT error is costly. For this reason, ADT values must be prepared as accurately as possible.

The current ADT factor method used by the New Mexico State Highway Department is calculated as shown in Equation 1.

$$\text{ADT} = \frac{\text{(Usable hours from coverage count)}}{\text{(Total from same hours from control station)}} \times \text{(ADT at control station for the previous year)} \quad (1)$$

When a short-term coverage count is taken, the total count is divided by the same period traffic counted at an individual permanent counter. A counter is selected as controlling that area, and is called the control station. A proportion is established of ADT at the permanent counter to the ADT at the coverage site. This is then multiplied by the ADT at the permanent counter site during the previous year. The result is a factored ADT used to estimate traffic volume at the coverage site.

Individual permanent counters are used to factor coverage counts throughout the state, and to make annual ADT adjustments when counts are not taken. Individual counters must be used to control extensive areas of roadway.

There is a 5- to 6-year cycle between coverage counts. Between the short-term coverage counts, how are ADT values determined for entry into the record? Each year, the permanent counter controlling the roadways in a given area is reviewed for percent change. This change ratio is then applied throughout the area controlled by that individual permanent counter.

How is a permanent counter station assigned to control a roadway? Usually the physically closest permanent counter on the same or nearby roadway is used as the control. There is sometimes a review of similar characteristics between the site of the permanent counter and where the short-term count is taking place. An Interstate location would not, for example, be used to control a nearby access road.

How are new permanent counter locations determined? The 5-year plan for highway construction and maintenance is reviewed for additional permanent control sites. If a roadway is being reconstructed, it is a relatively inexpensive addition to install a permanent counter. Before development of the present procedure, there was no cluster analysis of permanent counter locations. For example, two additional urban sites may be needed to establish a statistically valid group for that type of roadway. There could be a phase-out of current counter locations where there are unnecessary counters. Need for permanent counters on urban roads and overcounting of rural primary arterials were discovered while conducting the cluster analysis.

Over what period are the coverage counts conducted? The current method can incorporate traffic volumes 7 days of the week. Short-period 48-hr counts are the rule.

A major difficulty with the current New Mexico State Highway Department method is that the nearest permanent counter, even if it appears similar, may not be characterized by similar growth as the area it is used to control. Currently, permanent counter locations are used in two ways that affect the accuracy of ADT values. First, when a count is taken, the count is modified by the permanent counter that controls that area. Second, in the absence of a blanket or coverage count, the change in the permanent counter is used to calculate record ADT values. Although there undoubtedly is error in the adjustment during the count year, the primary concern of the quick cluster control method is error in noncount years as individual permanent counter change ratios are applied.

Cluster analysis of permanent counters is an alternative to the current individual counter method. Cluster analysis is placement of objects into groups (or clusters) suggested by information about the objects. In clustering, groups are defined by the data. Similarities and differences between objects may not be immediately apparent. Cluster analysis involves finding the greatest similarity among objects within a group, and the greatest difference between groups. All clustering methods are based on the same agglomerative procedure. Each observation, or permanent counter, begins in a unique cluster. The two closest clusters are merged to form a new cluster. Merging of closest clusters is repeated until only one cluster remains. Clustering methods differ in how closest clusters are defined. There are then statistical and application techniques employed to help determine the optimum number of groups.

Clustering was applied to the permanent counter locations in New Mexico, excluding those counters on the Interstate. The statistically based clustering results were then compared with results of clustering by functional classification of roadways on which the permanent counters are located.

The decision to explore clustering and to develop a quick cluster control method was based in part on the apparent deficiencies of the current method. The decision was also based on the cluster analysis recommended by the FHWA and used by other states. An outline of federal and state effort is helpful before detailing cluster analysis using New Mexico data.

What has the federal government encouraged and states other than New Mexico accomplished in use of cluster analysis? Much of the impetus for state-level research and development of cluster analysis has come from the federal government. A standard reference text is the *Guide for Traffic Volume Counting Manual (1)*, published in 1965. The technique identified for clustering was labor-intensive, unlike the rapid computer routines available today. The method involved color-coding a specific monthly group map for stations and groups of stations. Despite the lengthy procedure, open to a variety of manual errors, the document was helpful.

The Guide *(1)* identified use of a monthly traffic ratio (MTR), the ratio of monthly average weekday traffic (MAWDT) to AADT. It then documented two important characteristics that led the way to clustering of traffic volume data:

- The pattern of monthly variation of traffic volume persists over long stretches of highway, and
- The pattern of monthly variation of traffic volumes persists over long periods of time.

The group mean factor from cluster analysis may be applied to short-term counts located on road sections that fit within the group.

The Guide *(1)* recommended a minimum number of permanent counter locations within each group. It suggested four was the minimum for valid results. More permanent counter locations were recommended.

An updated version of the *Guide for Traffic Volume Counting Manual (2)* was published in 1970. It was clear the MTR values should be applied to short-term counts as an adjustment factor, and daily adjustment factors were ruled out. The Guide *(2)* averaged urban and rural MTR values to approximate suburban area ratios. There was a significant amount of refinement remaining.

The FHWA published the *Guide to Urban Traffic Volume Counting (3)* in 1981. This document notes that from three to five groups will be determined when 4-year averages of monthly data are used. The resulting MTRs are applied to weekday volume measurement as an adjustment factor. The Guide *(3)* encouraged the short-term weekday volume count as being no less than 48 hr in duration. It was noted that 48-hr counts pick up an additional 2 percent accuracy over 24-hr counts.

In 1985, the FHWA published the *Traffic Monitoring Guide (4)*. Appendix A of this Guide *(4)* outlines a clustering procedure for permanent counter locations. Using Statistical Analysis System (SAS) procedures, two criteria were used to select the optimum number of groups. A statistical indicator called the "cubic clustering criterion" was used. When this statistic reaches a minimum value, the corresponding number of groups is considered optimum. Additionally, when the R^2 statistic is significant, but the gains become modest, the optimum number of groups is indicated. When the results of these two rule-of-thumb tests vary, judgment is used to select the optimum number of groups. This judgment is based upon familiarity with the data and permanent counter locations.

What has been accomplished on the state level? In West Virginia during 1969, Pant and Wegmen *(5)* in *A Multiple Linear Discriminant Function Analysis* used classification count data for grouping truck weight stations. In 1971, Lieder *(6)* examined and amplified this work in *A Grouping Procedure*.

Pant established five groups initially, then reduced this number to four. When he tried various combinations of variables for defining groups, ADT and percent trucks gave inconsistent groupings.

This grouping procedure was successfully used by Pant and Wegman *(5)*. Lieder *(6)* modified and applied it to Texas truck weight and Maryland traffic data. Lieder found that the sum of least square differences provides good groups "if good judgment is exercised as to the cutoff," in optimum number of groups. Lieder also recommended that a minimum of 3 years of data should be used in the analysis. In other words, groups can be established using this procedure, although it requires judgment. The specification of multiple-year average data proved valuable in Lieder's work.

Sharma and Werner *(7)*, in Alberta, Canada, used cluster analysis in *Improvements in Travel Monitoring and Data Aspects of the Energy Problem*, published in 1981.

Sharma and Werner reviewed the existing literature, and focused on the *Guide for Traffic Volume Counting Manual (2)* and its use of MTR values. Sharma and Werner grouped 45 permanent counter locations. Of these, 44 were provincial primary highways. The other was secondary. Sharma and Werner used hierarchical grouping and wrote, "It has to be emphasized here that this method . . . does not indicate specifically what the optimum number of groups is for the study objectives."

Sharma and Werner *(7)* noted that the errors associated with each step of the grouping process identified a range of groupings. Establishing an effective range reduced the impact of subjective consideration in selecting an optimum number of groups. Their conclusion was that the optimum number of groups using this data was between 6 and 10. Still, in application, some specific grouping must be used. They selected the middle of the range, 8 groups.

This optimum number of groups was based on comparisons of mean monthly traffic factors. However, within the eight, Sharma and Werner *(7)* designated four primary groups, which were used for further analysis.

Sharma and Werner *(7)* analyzed the characteristics of the primary groups, which they termed "rationalization of resulting groups." Sharma and Werner were interested in different combinations of trip characteristics, such as purpose and length, among the groups. They used origin and destination studies as the basis of the analysis. From this work, the ADT values were improved, but they did not find a clearly distinguished load classification breakdown among the groups.

In Louisiana, Shah and Hirschmann *(8)* applied cluster analysis to permanent counter locations in *Analysis of Routine Traffic Count Stations to Optimize Locations and Frequency*.

Shah and Hirschmann *(8)* used 3-year traffic counts as the basis for the cluster analysis, which used functional classification. They wrote, "A clustering system crossing functional classes and/or parish lines was ruled out. A review of the results indicated that this method of analysis could not lend any valid interpretations in the determination."

Shah and Hirschmann *(8)* also noted that this was a limited study, not intended to be a complete statistical analysis. They used 3-year average statistics in accordance with observations from Dreusch's *(9)* analysis in Missouri in 1966 and Lieder's *(6)* 1971 research.

Hartgen and Lemmerman *(10)* wrote *Streamlining Collection and Processing of Traffic Count Statistics*, published in 1982. The work identifies application of ADT clustering techniques in New York State.

The motivation for their work was reduction in seasonal control stations. Through grouping assignment and other measures, they reduced counts by 35 percent with little or no reduction in information accuracy.

New York began with 12 factor groups when first applying cluster analysis. In 1975, this number was reduced to 8; in 1982, to 4. The judgment of Sharma and Werner *(7)* in moving from 8 groups in 1975 to 4 groups in 1982 paralleled the experience in New York.

After the clusters were compiled, it was determined that there was an unnecessarily large number of stations in some groups. Permanent counter stations were eliminated without negatively affecting the sample.

The four groups Hartgen and Lemmerman *(10)* determined by cluster analysis were

1. Urban or commuter,
2. Low-flow nonrecreational (less than 1,000 veh/day),
3. Rural long-distance, and
4. Recreational.

The variability of the estimates for the grouping ranged from 2 percent in Group 1 to 20 percent in Group 4.

After the groups were formed, they were analyzed by location, design, and use characteristics. After a fairly extensive analysis of variables, the results were interesting. "No combinations of these variables would perfectly distinguish the groups, but the urban/rural nature and access control of each highway appeared to have the greatest potential for making an initial distribution."

The New York application of cluster analysis used MTR values that could be characterized by urban or rural nature, and access control. This distribution is essentially by functional classification of roadways, with some reduction of the access and mobility distribution used in functional classification *(11)*. Other variable analysis was instructive, but did not enhance the groups.

The New Jersey Department of Transportation uses cluster analysis. In correspondence from Louis Whitely, Project Engineer, it was noted that clustering is done each year. Some shifting of counters among groups occurs. The grouping analysis is maintained through the rest of the year.

The New Jersey Department of Transportation is moving to a functional classification pattern for the groups that will appear as

1. Rural Interstate,
2. Urban Interstate,
3. Other rural,
4. Other urban, and
5. Highly recreational.

One of the implications of the cluster analysis has been the phasing-out of unnecessary permanent counter locations. The number of new locations required for some groups was far outweighed by the number of locations that could be removed from other groups. The result has been increased accuracy with smaller amounts of data that must be manipulated.

By the early 1980s, the federal guidelines and state applications of those guidelines had become refined. The technique of clustering permanent counters was demonstrated in a variety of settings. The use of computers made cluster analysis a relatively easy procedure, requiring small personnel time commitment after the initial analysis was complete. What has the use of clustering shown? A minimum of 3 years' data, with a minimum of four to six counters in each cluster, provides helpful MTR values. Finally, the use of clusters based on functional classification should be carefully examined from work in Louisiana and New York, as well as developing procedures in New Jersey.

If cluster analysis can be successfully conducted, will this methodology significantly improve the accuracy of ADT calculation? Based on the answer to this question, a quick cluster control method may be developed.

Cluster analysis was used to define groups of permanent control stations in New Mexico. All permanent counter locations not on the Interstate were clustered. Not all New Mexico permanent counter stations have full-year data available. Some 28 stations had sufficient data for analysis.

The SAS PROC CLUSTER was used. This program performs hierarchical clustering of observations using 1 of 11 agglomerative methods. The clustering method selected was Ward's *(12)* minimum variance method. Ward's, along with squared Euclidean distances, generally produces the best clustering results. Ward's method is based on minimizing the within-cluster sum of squares.

The initial cluster was for 1-year data. The most recent year for which there were complete data was used. A total of 12 monthly traffic factors were developed for each station. Initially no multiple-year averaging was done.

What did the analysis show? The clustering produced eight groups of permanent control stations. What were the indicators used to identify the optimum number of groups? The R^2 statistic was confident at the 95 percent level at eight groups,

TABLE 1 CLUSTER ANALYSIS GROUPS, BASED ON 4-YEAR AVERAGE DATA

Group	Functional Classification	General Location
Group 1		
C7S	Rural primary arterial	North of Santa Fe–NU Limit
A10S	Rural minor arterial	South of Taos
A40	Rural primary arterial	NM 68 north of Taos
A41	Rural primary arterial	NM 44 at Cuba
A87	Rural primary arterial	North of Silver City
A107E	Rural primary arterial	North of Alamogordo to Cloudcroft
A113	Rural primary arterial	West of Ft. Sumner
A105	Rural primary arterial	East of Ruidoso
Group 2		
A115	Rural minor arterial and major collector	North of Clovis
A34N	Rural primary arterial	North of Cedar Crest
A107S	Rural primary arterial	North of Alamogordo to Tularosa
SFC	Urban primary arterial	Cerrillos Road in Santa Fe
SFD	Urban primary arterial	St. Francis Drive in Santa Fe
B119	Rural primary arterial	South of Roswell
A32S	Rural minor arterial and major collector	South of Armijo
A119	Rural minor arterial and major collector	South of Roswell
CBD–B	Urban minor arterial	Canal St. near Plum in Carlsbad
Group 3		
B59	Rural primary arterial	West of Aztec
CLO–A	Urban primary arterial	West of Grand Avenue in Clovis
B124	Rural minor arterial and major collector	South of Lovington
A59	Rural primary arterial	South of Farmington
A–74	Urban minor arterial	Southwest of Las Cruces
ALB–AA	Urban minor arterial	US 85 in northwest Albuquerque
A–124	Rural minor arterial and major collector	South of Hobbs
ALB–SM	Urban primary arterial	San Mateo in Albuquerque
Group 4		
A25W	Rural primary arterial	US 56 at Abbott
B40	Rural primary arterial	US 84 south of Jct. NM 96
A28	Rural primary arterial	East of Raton

but dropped below this level when at seven groups. There was a significant change in the semipartial R^2 from the eighth to seventh group.

An important observation in selecting optimum group size is the cubic clustering criterion (CCC). This statistical indicator was referred to previously in discussion of the 1985 edition of the *Traffic Monitoring Guide (4)*. CCC is based on the assumption that a uniform distribution on a hyper-rectangle will be divided into same-sized hypercube-shaped clusters. Performance of the criterion, evaluated by Monte Carlo methods of

TABLE 2 MONTHLY TRAFFIC RATIOS FOR CLUSTER ANALYSIS GROUPS, BASED ON 4-YEAR AVERAGE DATA

	Group 1	Group 2	Group 3	Group 4
January	.8196	.9045	.9127	.905
February	.8284	.9292	.9301	.9195
March	.9163	.9847	.9673	.9613
April	.9078	.9937	.9959	.9911
May	1.0112	1.0284	1.0248	1.0495
June	1.1063	1.0603	1.0502	1.0622
July	1.2029	1.0669	1.0535	1.0637
August	1.1897	1.059	1.0517	1.0617
September	1.043	1.0097	1.03	1.0094
October	.9994	.9944	1.0135	1.0017
November	.9218	.9713	.9749	.9563
December	.9156	.9573	.9710	.9825

TABLE 3 MONTHLY TRAFFIC RATIOS FOR FUNCTIONAL CLASSIFICATION GROUPS, BASED ON 4-YEAR AVERAGE DATA

	Group 1	Group 2	Group 3	Group 4
January	.82036	.90406	.72369	.68703
February	.83461	.92645	.71501	.62619
March	.9136	.97577	.87733	.77827
April	.92669	.99466	.79259	.73566
May	1.03769	1.03345	.92189	.92400
June	1.11942	1.05956	1.12623	1.13344
July	1.20107	1.05946	1.43332	1.63359
August	1.18041	1.05633	1.43569	1.57033
September	1.03756	1.01803	1.04732	1.16169
October	1.01296	1.00308	.93376	1.00964
November	.9553	.96968	.78611	.79651
December	.92296	.96541	.82738	.90812

expected R^2 values, may tend to be conservative given the number of permanent counter locations being clustered *(13)*. PROC TREE was also used. This procedure creates dendograms using output from PROC CLUS.

The SAS statistics manual and CCC technical manual identify selection of the optional number of groups from a plot of the CCC. There should be one number that increases in a slight peak. In use of this statistical indicator, a plot of the CCC has proven more useful than the CCC value alone. From a plot, multiple peaking characteristics may be quickly identified that may raise questions concerning the optimum number of groups. In most instances, there is no difference between the lowest CCC value, as suggested in the *Traffic Monitoring Guide (4)*, and clusters indicated by a plot of the CCC and cluster group dendogram. When a difference exists, it is by one or two groups. The optimum number is resolved by reference to the R^2 value. In the initial cluster analysis, the CCC plot progressed consistently only through the eighth group.

Graphically, and from key statistics in the computer output using 1-year data, the identified optimum number of groups was eight. The same process of selecting optimum group size was used in all subsequent cluster analyses.

The next step in the cluster procedure was to run multiple-year data. SAS PROC CLUS and PROC TREE were used with 4-year average ADT data. Table 1 is a list of the four groups established by cluster analysis.

The MTR by group, based on 4-year average data, is shown in Table 2. There is limited application of these MTR values. An area where an MTR value is applied must have an established history to group it using the CCC.

Of the four clusters identified, two clusters had adequate or more than adequate stations for the sample. Groups 1 and 2 had an adequate sample of permanent counter locations, whereas Groups 3 and 4 did not have an adequate number of samples. Groups with an adequate sample of counters had a small standard deviation among individual counter MTR values. Where there was a small sample as in Group 3, the standard deviations increased. This fact indicated the importance of an adequate number of observations within groups formed by cluster analysis.

Group 2 is on the borderline for an adequate sample. The absence of one of these counters in 1981 caused the Group 2 ADT adjustment factor to be invalid for that year.

Next analyzed were clusters based on functional classification. This analysis established four functional classification groups, not including rural and urban Interstate. Table 3 presents MTR values for each group. The groups are shown in the following:

Group No.	*Functional Classification*
1	Rural primary arterial (Functional System Code 02)
2	Rural minor arterial and rural major collector (Functional System Codes 06 and 07)
3	Urban primary arterial (Functional System Codes 12 and 13)
4	Urban minor arterial (Functional System Code 16)

All current permanent counter stations not on the Interstate are on roadways that fit one of these categories. Stations by funcitional classification group are as follows:

Group No.	*Permanent Counter Locations*
1	C7S, A40, A41, A87, A107E, A34N, A107S, B119, B59, A59, A25W, A28, B40, A105, A113
2	A115, A32S, A119, B124, A124
3	SFC, SFD, CLOA, ALBSM
4	A10S, CBDB, A74, ALBAA

Identified in the analysis were two rural and two urban groups: rural primary arterials, rural minor arterials with major and minor collectors, urban primary arterials, and urban minor arterials with major and minor collectors. The rural road MTR values for primary arterials are distinct from MTR values for minor arterials and collectors. Other rural roads, a category used in previous studies, was not indicated. Because of the limited urban sample, use of two urban groups rather than a single group of other urban roads cannot be established with the same certainty. On the basis of the rural data, however, two urban groups are retained until further permanent counter data are available.

The MTR by functional classification corresponds closely to the ratio by cluster analysis for Groups 1 and 2. Where there is an inadequate sample (e.g., Groups 3 and 4), the MTR values are not similar. This fact reinforces the conclusion that a representative sample of no less than five, and preferably more than five, permanent counter sites is needed in each group.

There is a higher within-group standard deviation for groups based on functional classification than those based on PROC CLUS and CCC. The standard deviation is considerably higher for Group 1, only slightly higher for Group 2.

Given similarities in groups and MTR values, a major advantage of clustering by functional classification is application. Any count site can be immediately identified by functional classification, and the corresponding group MTR applied in ADT calculation. When short-term counts are taken in areas with uncertain permanent control stations, the group mean for counters with the same functional classification may be used to factor the count to ADT value and to adjust record ADT data between count years. This approach is also attractive because it is simple to apply and there is an improvement in methodology and results without adding staff time.

Clustering by functional classification provides usable results, with immediate site application for ADT calculation. A quick cluster control method can be identified to implement clustering.

The quick cluster control method is based on comparing cluster with individual permanent counter ADT adjustments. Record data are used in the comparison. In selection of comparison sites, the period between counts at a given location should be 4 to 5 years, and a new count should have been recently taken.

As has been discussed, there must be at least 3 years' data for a minimum of five permanent counts in each functional classification cluster. The usable clusters must have the same functional classification as the sites selected.

From an initial count at the comparison sites, each year the record ADT data are adjusted or factored by an individual permanent counter. After a new blanket count was conducted at the comparison points, the count was adjusted and a new ADT value established. The difference between the new count-based ADT and the ADT based on individual permanent counter factoring is the factoring error. In some instances, the difference between the factored ADT and count-based ADT is slight. In other instances, the difference is significant.

Cluster by functional classification provides a basis for factoring the ADT between blanket counts, as well as adjusting the count to ADT. At whatever year there is an available cluster factor, it is used to adjust the record ADT to the following year. The cluster factor adjustment is made from year to year, until the same comparison with recent count-based ADT can be conducted as was done with the individual permanent counter. The difference between the cluster-factored ADT and recent count-based ADT establishes the cluster factoring error for that comparison point.

The individual permanent counter and the cluster analysis factored ADT values can then be compared. The factoring errors can also be compared.

Where the difference between the cluster ADT and permanent counter ADT is less than 100 vehicles, the conclusion is that the roadway is equally controlled by both. The traffic recording devices are accurate roughly within a range of 50 veh/day. Because the error of the two counts being compared may vary in the opposite direction, improvement of less than 100 veh/day is discounted. In applying New Mexico cluster factors, there was a limited number of years' adjustment, particularly for Group 2, rural minor arterial and major collector. In the future when more years' adjustment is made, the difference between cluster and individual permanent counters will be more significant in some areas currently equally controlled. In some areas the result of more years' data will be controlled by an individual permanent counter. In other areas there will be more accurate control by cluster analysis.

When the cluster analysis ADT was closer to the recent count-based ADT and the difference was greater than 100 vehicles, the area was considered controlled more adequately by cluster analysis. When the permanent counter ADT was closer to the recent count-based ADT and the difference was greater than 100 vehicles, the area was considered controlled more adequately by individual permanent counter. Where two adjacent points of comparison on the same roadway were controlled by different procedures, a major generator or crossroad was selected between the points of comparison. This procedure was used to separate the control areas.

Comparable benefits of cluster analysis or individual permanent counter analysis can be shown in several ways. The comparisons are based on the last-factored ADT. The numeric difference between the individual counter-factored ADT and the cluster-factored ADT is determined. If the number is less than 100, the procedure stops, and the site is considered equally controlled. If the number is larger than 100, it is divided by the recent count-based ADT. The resulting percent closer to the count-based ADT that one factor method is than the other is an overall measure of accuracy.

This overall measure of increased accuracy for the factoring method represents between 2 and 3 years of ADT adjustment. The number of years of ADT adjustment is divided into the overall measure of accuracy. The result is the annual improvement in ADT accuracy one factoring method provides over the other. This annual improvement may then be multiplied by the number of years an ADT must be factored before another blanket count is taken. This procedure gives a total between-count improvement of accuracy of one method over another at a given point of comparison.

Another way in which the benefit of clustering is determined is in forecasting. The log data for a given point from year to year are used in multiple regression analysis to forecast ADT to design year. Best-fit regression analysis can be used with no R^2 value of less than 0.90. A forecast for each point of comparison is conducted, once with the permanent-counter-factored ADT values and once with the cluster-analysis-factored ADTs. The difference in results will be substantial at many points of comparison.

The cluster control method used in New Mexico is quick because it accepts initial and subsequent count factoring using the individual counter method. It also accepts whatever between-count years' data have been factored by individual counters when cluster data are unavailable. As much of the current methodology is accepted as possible, while demonstrating the benefits of clustering. This approach tends to favor the existing method. The distinction in design year projections for ADT would be more significant if the initial and all subsequent ADT values were adjusted by cluster analysis. The tendency to favor the existing methodology is acceptable because it facilitates the quick calculation of control areas, and communicates to decision makers that clustering improves accuracy.

Site-specific examples of the quick cluster control method are helpful. Two areas were selected, the city of Taos, and Chaves County, New Mexico. The sites were selected because there was a lengthy period between counts, adjusted recently on the basis of a new count.

Where clustering improved ADT factoring, typically 3 to 4 percent per year improvement in accuracy was provided. This resulted in an average of 15 to 20 percent improvement in accuracy between blanket counts. At some locations sampled, the increase in accuracy through clustering reached 8 to 10 percent per year, or 40 to 50 percent improved accuracy between counts. Where permanent counter controls had large error in adjusting ADT, the resulting forecast using inaccurate record data overestimated future demand by more than a lane of traffic. The use of record ADT data for design year forecasts makes critical the use of cluster adjustment at appropriate locations.

Use of clustering by functional classification as a standard procedure in ADT calculation and factoring can improve ADT accuracy. Use of the quick cluster control method can encourage and facilitate use of clustering in traffic volume estimation.

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