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Radar-Platoon Technique for Efficient and Complete Speed Measurements

SAM YAGAR AND MICHEL VAN AERDE

A technique by which a single observer can accurately estimate speeds of all vehicles in a single lane of traffic with the use of a radar device, regardless of the volume of traffic in that lane, is described. This is accomplished by considering platoons of vehicles rather than each individual vehicle. For each platoon, the speed, platoon composition, and lead-vehicle type are recorded. The speed is measured by means of a radar unit while the platoon composition and platoon lead-vehicle type are observed visually and recorded manually. On two-lane highways, this technique can provide detailed volume counts and speed measurements for one direction of traffic flow and summarized (e.g., 5-min) vehicle counts for the opposite direction. For total two-way volumes of less than 500 vehicles/h, the single observer can provide detailed volume counts and exact speed measurements for both directions.

Although there exist many direct and indirect methods for measuring the traffic characteristics of a highway, they tend to be geared toward one specific type of measurement and do not produce, by themselves, the type of complete data that are required for a thorough analysis of highway performance. Any extra data must therefore be obtained by using other techniques and additional resources. Some of these basic data-acquisition methods are listed below and described in a previous paper (1):

1. Volume counts--visual observation, mechanical counter, and microcomputer; and
2. Speed measurements--license-plate matching, stopwatch technique, microcomputer, and radar.

There are many indicators that either individually or collectively indicate how effectively a highway accommodates various levels of traffic. The total number of vehicles and the average speed of these vehicles are two of the most commonly obtained statistics. Although speed and total volume are perhaps the most important indicators of the operating performance of a highway, other types of data are needed for a more complete analysis.

It is often important to know the vehicle composition of the traffic stream, for one can seldom consider either a truck, a bus, or a motorcycle to be equivalent to a car in this regard. In addition, one is also interested in the spatial distribution of these vehicles, for again it is important to know if these vehicles are all traveling as a single group, known as a platoon, or as individual, independent units.

Similarly, one needs to know more than just the average speed of all vehicles. To know the frequency distribution of their speeds and to determine to what degree drivers are prevented from driving at their desired speeds are often of equal or even greater importance.

Obtaining this type of complete data has been expensive and time consuming. One could either employ excessive amounts of resources or settle for a smaller data set.

With this thought in mind, the radar-platoon technique was developed and tested (2). After 500 h of application in the field it has been found to be fast, accurate, and relatively inexpensive in terms of time and money. These advantages make this method for monitoring the performance of a highway most efficient and highly practical.

DESCRIPTION OF RADAR-PLATOON TECHNIQUE

The radar-platoon technique for obtaining traffic data is based on the use of a radar unit for measuring speeds and the division of the traffic flow into platoons for the purpose of assigning these speeds. Whereas various other techniques for measuring speeds require either extra calculations or several people to take a single reading, the radar unit operated by a single individual automatically produces instantaneous values of speed.

Even with the radar unit, it is not always possible to individually record the speed of every vehicle that passes by, especially at higher volumes. However, vehicles tend to form groups (platoons) at these higher volumes. Since platoons travel as one unit, the average speed of the platoon can be taken to adequately represent the speed of each member of that platoon for most practical purposes. The division of the traffic flow into platoons therefore allows a representative speed of each vehicle to be recorded.

The radar-platoon technique consists of counting the number of vehicles of each type in each platoon, recording the platoon lead-vehicle type, and recording an average speed of the given platoon from the radar unit. This can be accomplished without great difficulty by a single person, as the speeds of vehicles in a platoon are virtually identical.

All data collection for a given location is carried out by one person positioned along the road. The data-collection equipment should be sufficiently removed from the lane in which the traffic is moving (about 5 m or more, if possible) so that it does not affect traffic and preferably on the same side of the road as the principal-flow lane. Although the equipment usually consists of a vehicle that houses the radar set and operator, it is preferable to have the operator completely off the roadway, with only the radar antenna at the side of the road and camouflaged in some manner.

The use of the radar-platoon technique is described in terms of two-lane highways where it has been principally used to date. From the selected

Figure 1. Typical roadside radar setup.

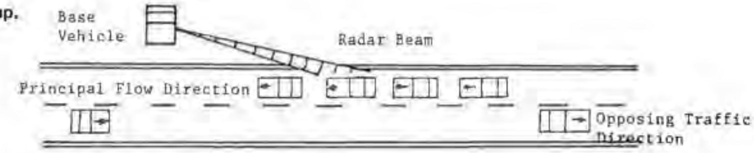
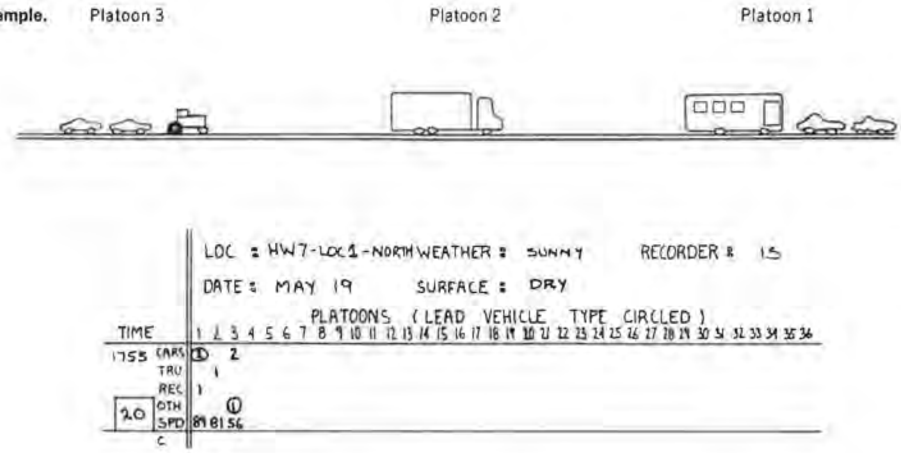


Figure 2. Data-recording example.



site the radar is trained on the oncoming traffic that is moving in the principal-flow direction. Positioning the vehicle and setting up the radar unit take approximately 10 min. The person is then ready to begin collecting data from either inside or outside the base vehicle. A typical geometric configuration is illustrated in Figure 1.

As discussed above, under certain terrain conditions, one may wish to collect data without having to park a vehicle on or adjacent to the roadway. In that case the power supply for the radar unit can be a portable car battery. In either case, the radar power drain is sufficiently small to allow one to collect data for at least 18 h before recharging the battery.

Obtaining Data for Principal-Flow Direction

The study period is divided into a series of consecutive time periods (5 min is recommended), during which traffic characteristics can be considered as effectively time stationary. All data collected during this 5-min period become a single record of information.

The observer considers platoons of vehicles that are observed to be traveling together. These platoons can be easily identified as a group of vehicles that are traveling close together at a common speed, i.e., following a lead vehicle that restricts the speed of any followers.

As each such platoon moves by in the principal-flow direction, the number of vehicles of each type (i.e., cars, trucks, recreational vehicles, etc.) are counted and the type of vehicle that leads the platoon is noted. Also, a single speed can be recorded that is representative of the speeds of all vehicles in the platoon. The fact that there is only one speed for each platoon is part of our definition of a platoon and makes it possible for a single person to record all of this information. If the observer feels that one vehicle is overtaking another or falling behind, he or she need not treat them as being in the same platoon. The platoons are later aggregated during the data-processing phase to obtain any summaries required for the 5-min period, such as total volume, average speed, etc.

Figure 2 illustrates a series of three platoons traveling at speeds of 89, 81, and 56 km/h, respectively, and the recording of these platoon characteristics on a data sheet.

Data on Opposing Traffic Flow

Simultaneous to the data collection for the principal-flow direction, the opposing traffic volume is counted on a hand-held counter. For the opposing direction, no distinction is made with respect to either platoon size, platoon lead-vehicle type, or the type of vehicles in the platoon. At the end of the 5-min period, the accumulated total opposing traffic volume is recorded and a new period begins where the previous one left off.

Data Sheet

A typical data sheet, which has been used in Ontario, is illustrated in Figure 3. This sheet, which is approximately 21x36cm, has been reduced for recording the data-collection site, date, weather, and surface conditions as well as the name of the recorder. On the data sheet in Figure 3 there is room for a total of 36 platoons in each 5-min period. If this number is not exceeded for any 5-min period, data for a full hour (12 5-min periods) can be recorded on one sheet.

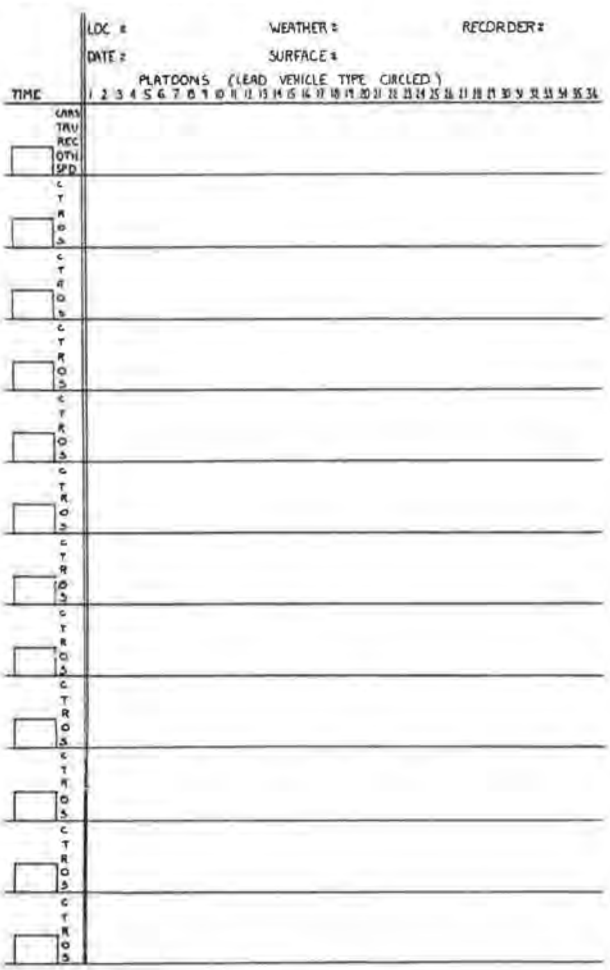
As stated previously, data are collected for consecutive sets of 5-min periods. On the data sheet a five-line record has been reserved for each such time period. A single vertical column of five squares represents the relevant characteristics of a single platoon, as shown in Figure 2. The number of cars, trucks, recreational vehicles, and other vehicles and platoon speed is recorded in that order.

The platoon lead vehicle is recorded by using the convention that the lead vehicle of each platoon is circled unless there is only one vehicle type, in which case the single vehicle type must be the lead vehicle by default.

TYPES OF INFORMATION PROVIDED BY RADAR-PLATOON TECHNIQUE

The radar-platoon technique yields a complete data

Figure 3. Data-collection sheet.



set, which is described below in the various categories.

Detailed Volume Counts

The procedure yields total volume counts for each direction and a breakdown into the various types of vehicles for the principal-flow direction. A total vehicle count is usually used as a measure of road use. It is obtained by summing the number of vehicles of all four types over the given time period.

A more representative measure of road use is obtained when the heavier and longer vehicles, such as trucks or recreational vehicles, are weighted more heavily than standard passenger cars. A classification count can more accurately represent traffic conditions as larger vehicles take up more space, are more difficult to overtake, and cause greater deterioration of the road surface.

Detailed volume counts are more useful than simple aggregated totals, as they can be more fully analyzed and manipulated in the analysis stage of a study. The volume of opposing traffic is useful as it can be a critical factor that restricts the passing maneuvers of the vehicles traveling in the principal-flow direction. Passing, or the lack of it, can break up or cause platoons, respectively. Such platoon formation behind slow moving vehicles has a direct bearing on speeds and quality of service.

One-Way Speeds

The radar method of measuring speeds yields accurate data on each vehicle traveling in the principal-flow direction. This method of data collection is therefore very efficient and, the fact that a 100 percent speed sample is obtained, makes the procedure unbiased either toward or against a particular type of vehicle.

Another major advantage of using radar is that it yields spot speeds as opposed to space average speeds. Other methods of collecting speed data rely on measuring the length of time that a vehicle requires to travel a given distance. The ratio of the distance over time is then used to yield a space average speed for the entire section. However, different factors influence traffic to varying degrees as one travels along any finite section of highway. When using a space average speed approach, these factors are therefore difficult to isolate. In contrast, the spot method yields instantaneous values of speed. These instantaneous values of speed are linked more closely to any set of influencing factors so that their specific impacts can be analyzed.

Two-Way Speed Measurements

For high traffic volumes, detailed counts and speed measurements are taken only for the principal-flow direction. However, when the combined volume for both directions is less than 500 vehicles/h, the radar set can be trained to track vehicles in both directions. An experienced data collector can then obtain speeds, count the individual types of vehicles, and record the platoon lead vehicles for both the principal flow and the opposing traffic. The simultaneous analysis of two directions significantly improves the efficiency of the data-collection process. Also, this type of data can have a higher information content by providing more detailed information on opposing flow for each direction.

At higher volumes it becomes very difficult to visually monitor the data for both directions simultaneously. There is too much work for a single observer, and the principal flow of traffic also eclipses the radar beam, which makes it very difficult, if not impossible, to use the radar for the opposite direction. Complete simultaneous traffic analysis of two directions by a single recorder is therefore restricted to low volumes by both human and mechanical factors.

Platoon Measurements

The behavior of individual drivers can be highly dependent on other users of the highway, especially at higher volumes. A driver is generally influenced by, and sometimes completely restrained by, the vehicles that are either ahead or behind, as well as the oncoming traffic. It is therefore important to study both the behavior of the platoon and the behavior of the individual.

The radar-platoon technique yields directly the type of information required for this type of consideration. Each record contains the size, speed, composition, as well as the leader of each platoon.

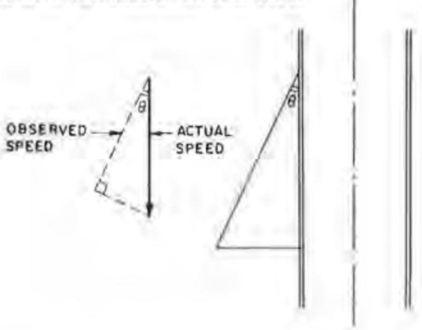
EQUIPMENT CONSIDERATIONS

In setting up, describing, and using the equipment, a number of factors should be considered. These are described below.

Positioning of Equipment

The selection of a site for positioning the radar

Figure 4. Geometric factor for measurement at an angle.



set is determined by two opposing factors. The site that is chosen should therefore be a compromise between these factors. It is very important that the data-collection process not interfere with or affect the natural, normal traffic flow by creating curiosity or fear of a speed trap. If this does occur, speeds may be artificially low and of questionable value in any statistical analysis.

In order to avoid interference problems, the radar set should be well hidden and the observation vehicle should be parked as far off the road as possible. Unfortunately, as one moves away from the road, the angle between the road and the radar beam becomes larger. While small angles produce only insignificant errors, the use of larger angles results in a considerable underestimation of the speed of the vehicle. The geometric factor is illustrated in Figure 4. The calculations and table below can aid in the selection of the most appropriate distance from the road for the radar set:

Measured = actual x cos θ.

Error = actual - measured = actual (1 - cos θ).

Percentage error = (error/actual) x 100 percent
= [actual (1 - cos θ) x 100 percent]/actual
= (1 - cos θ) x 100 percent.

Angle (°)	Error (%)
0	0
2.5	0.10
5	0.38
7.5	0.86
10	1.52
15	3.41
20	6.03

Calibration of Equipment

The utility of the collected data can be no better than the accuracy of the data; it is therefore essential that the radar equipment that is being used be in good operating condition. The radar unit is equipped with an internal calibration circuit. This circuit should be used to check the operation of the internal parts at least once every hour. Each set up of the microphone or antenna should be checked by means of a set of tuning forks. No further data should be obtained once the radar unit fails either test, as such data would be invalid.

During the data-collection process the persons operating the radar set should always ensure that the values of the digital readout are compatible with visual estimates. Any inconsistencies should be noted along with the data that may be affected.

OTHER CONSIDERATIONS IN USING RADAR-PLATOON TECHNIQUE

Some factors that one should consider in designing a data-collection technique and recording form are described below.

Weather and Surface Factors

Weather and surface conditions are important factors that influence the speeds of the drivers and the capacity of the highway. It is therefore essential that the prevailing weather and surface conditions be carefully recorded on each data sheet. Although the weather and surface conditions can be described in great detail by using several adjectives, the use of the computer restricts this vocabulary to a set of letter codes, as shown below:

1. Type of vehicle (leader to be marked by a circle)--C, car; T, truck; R, recreational; and O, other.
2. Weather--S, sunny; O, overcast; R, rain; F, freezing rain; S, snow; D, drizzle; and C, clear.
3. Surface--D, dry; W, wet; I, ice; S, snow covered; C, center bare; L, slush; and A, damp.
4. Location code--highway number, 1-9 (e.g., highway 8, northbound, location 2); direction, N, W, S, and E; and location, 1-9 (e.g., 8 N2).
5. Date--month, day, hour, and minute (e.g., July 20, 7:35 p.m. = 07201935).
6. Recorder--identified by initial of surname or other single-digit code.

In general, weather and surface conditions should be updated every 5 min (if changes occur). When a dramatic change takes place during a 5-min cycle, the conditions that were dominant are assigned to the entire period or, alternatively, that period can be eliminated. Very sudden and drastic changes or exceptional circumstances should be noted alongside the affected data.

Cycle Length Selection

A counting cycle of 5 min is recommended because either a longer or a shorter cycle would lead to increased difficulties. In addition, 5 min is a convenient time span for calculations and physical checks.

The radar-platoon technique is based on the fact that speeds can be accurately assigned to each platoon that passes the observation site during the timing cycle. During a 5-min cycle, an average of approximately 20 platoons will go by. This means that if the last platoon in each 5-min cycle runs over into the next time period, at the most 5 percent of all the platoons will need to be broken up between the adjacent two time periods. However, this percentage doubles if the time period is cut in half and becomes 25 percent when the cycle length is 1 min.

The above argument favors long counting cycles. However, as cycle length increases, the data become more aggregated and special conditions that prevail for only a short time become hidden in the remainder of the data with which they are averaged.

For those two reasons a time length of 5 min was chosen as being short enough to show any short-term fluctuations and yet long enough to keep the number of split-up platoons to an acceptable level.

Platoon Measurement

A platoon is a physical group of vehicles whose motions are interdependent. The speed of a platoon is dictated by the lead vehicle. The speeds of the following vehicles might fluctuate slightly but their average corresponds approximately to that of the leader. This average speed is assumed to be representative of the whole platoon and is recorded on the data sheets. It is quite simple to mentally integrate and average the speed of a platoon as the speeds do not fluctuate significantly, and the recorder is provided with a relatively long time to record the platoon speed if the platoon is long.

Even when the number of broken-off platoons is kept to 5 percent by the use of a 5-min cycle, as described in the previous section, it is important that both the recorder and the person who will eventually analyze the data have the same understanding as to how this 5 percent will be treated. Furthermore, this convention is intended to treat these split-up platoons in such a way that in the final analysis they will represent the actual events as close as possible.

Small platoons that pass by during the cycle change-over period are assigned to the cycle during which the major portion of the platoon went by. This will underestimate the volume in one cycle and overestimate the volume in the next, but the characteristics of the platoon will be correctly represented.

Very large platoons (i.e., 20 or more) that span 2 cycles can be broken up into two parts, one in each cycle. The platoon assigned to the second cycle is then given the same lead vehicle as the original platoon. When the same type of vehicle is not present in the second part of the platoon, a dummy vehicle can be added to represent the correct lead-vehicle type, or a new leader assigned, depending on the purposes of the study.

Vehicle Type Categorization

When selecting the number of different types of vehicles that are to be distinguished and counted separately, one must trade-off between theoretical and practical requirements. From a theoretical standpoint one would like to divide the users of a highway into as many different types of vehicles as possible. Such a procedure allows for a highly detailed analysis of traffic behavior according to vehicle type. However, to set up a very large number of different types of categories is usually not very practical in terms of either data collection or analysis.

On the other hand, if one aggregates all vehicles into just one or two categories, one may sacrifice some important effects that result from having different types of vehicles use the same road.

In view of the difficulties that are associated with each extreme, one must make a compromise by selecting enough categories to distinguish the major differences, yet aggregate sufficiently so that the data-collection and analysis processes remain manageable.

Based on this argument it was decided in an Ontario study (2) to split up the different types of vehicles into four different groups: passenger cars (including vans and light 2-axle, 4-wheel trucks), larger trucks, recreational vehicles, and others. The choice of these four categories served our needs, yet the data-collection aspects were not unwieldy. The other category was included as a catch-all for undefined categories. Under special circumstances, more or fewer divisions can be made but in such cases a different data sheet from the one illustrated in Figure 2 would need to be constructed.

ADVANTAGES OF RADAR-PLATOON TECHNIQUE

The radar-platoon technique has both technical and economic advantages over existing state-of-the-art techniques. These advantages are briefly described below.

Technical Advantages

The radar-platoon technique creates an unbiased data set since the speed of each vehicle is represented. This is a significant improvement over most other techniques that only consider a sample of the vehicles.

The vehicle counts and the speed measurements are accurate as each vehicle is counted manually and the speeds are measured by using calibrated radar sets. No difference could be detected between measurements of independent observers. The recognition of platoon formations is a type of surrogate measure of service levels that could not be obtained from any of the previous techniques.

The simplicity of the technique eliminates the need for skilled operators, which in turn eliminates lengthy training requirements. Even unstable platoons can be handled with this method. The setup is highly mobile and, as a result, several different locations can be sampled without duplication of capital costs or difficult setups.

The thoroughness of the radar-platoon technique is illustrated by the sample output of summary data in Figure 5. The summary for each 5-min period is printed on a single line and consists of six basic sections. The first block describes the weather and surface conditions at the given date and time. Next, the total number of platoons and their breakdown according to lead-vehicle type are given. The third block has the total vehicle counts for each vehicle type and then for each direction. The fourth block gives the passenger car unit equivalents for each direction. The final two blocks of numbers represent the speed distribution for each 5-min period. This distribution is described by its average, low, and high speeds and then the percentile speeds from the 10th to the 90th.

Economic Advantages

The initial capital cost of the radar-platoon technique is small if no radar set needs to be purchased. The counter used for counting the opposing volume is inexpensive and the remainder of the equipment is available in the form of standard office supplies.

The variable cost of operating a monitoring station is also kept to a minimum because only one person is required to operate each such station. Each station also produces an additional count for opposing traffic. The data-collection technique yields a maximum return of data during low volumes when two-directional data are obtained.

CONCLUSIONS

The radar-platoon technique for collecting traffic data is fast, relatively inexpensive, requires a minimum of manpower, and provides a 100 percent sample of speeds. The distinction between different vehicle types allows for the evaluation of the effect of different vehicle type distributions on the behavior of traffic. The use of platoons as a measure of highway performance recognizes that individual vehicles may be affected by the other users of the highway. The count of the opposing traffic volume as well as the principal traffic flow provides a means of evaluating the impact of different directional traffic splits. The effect of slow moving vehicles can be determined through the analysis of the platoon lead-vehicle types.

The spot values of vehicle speed and traffic volume provide a direct means of establishing the relation between speed and volume for a set of specific highway conditions. The ability of mea-

Figure 5. Sample output of 5-min summaries and overall summary for data location.

**************			PLATOONS/LEADER					*****VEHICLE COUNTS******							*PCU PER HOUR*			***SPEED***			********PERCENTILE SPEEDS*********								
DATE	TIME	W/S	TOT	CA	TR	RE	OT	CAR	TR	RE	OT	MAI	OPP	TOT	MAI	OPP	TOT	AVG	LO	HI	10	20	30	40	50	60	70	80	90
905	945	O D	17	12	4	1	0	19	4	1	0	24	36	60	342.	513.	855.	91.	82.	104.	84.	86.	88.	89.	90.	91.	92.	95.	99.
905	950	O D	18	18	0	0	0	29	1	0	0	30	23	53	372.	285.	657.	88.	75.	110.	77.	79.	80.	82.	85.	91.	94.	95.	104.
905	955	O D	18	17	1	0	0	37	1	0	0	38	26	64	468.	320.	788.	83.	61.	98.	64.	76.	79.	81.	84.	87.	91.	93.	96.
905	1000	O D	17	16	1	0	0	28	3	0	1	32	47	79	432.	635.	1067.	83.	74.	95.	75.	76.	78.	80.	82.	84.	87.	89.	91.
905	1005	O D	17	14	3	0	0	27	5	0	0	32	42	74	444.	583.	1027.	87.	79.	108.	82.	83.	84.	85.	87.	88.	90.	91.	93.
905	1040	O D	18	13	5	0	0	30	6	0	0	36	28	64	504.	392.	896.	80.	70.	98.	71.	72.	75.	77.	78.	81.	84.	86.	94.
905	1045	O D	10	6	3	0	1	11	3	0	1	15	16	31	228.	243.	471.	81.	70.	91.	70.	73.	78.	82.	83.	83.	85.	86.	90.
905	1050	O D	14	12	1	1	0	24	2	1	0	27	30	57	354.	393.	747.	83.	69.	96.	71.	75.	76.	78.	80.	86.	91.	94.	95.
905	1055	O D	25	23	2	0	0	35	2	0	2	39	32	71	516.	423.	939.	90.	77.	112.	79.	83.	84.	85.	86.	89.	92.	98.	104.

***** SUMMARY OF LOCATION 7 E 1 *****

		VEHICLE	COUNTS-PERCENT		LEADS-PERCENT		VOLUMES	
5-MIN PERIODS :	132	CARS :	3994	90.8	1924	89.6	MAIN :	4398
TOT PLATOONS :	2148	TRUCKS :	266	6.0	151	7.0	OPPOS :	4023
		RECS :	71	1.6	46	2.1	TOTAL :	8421
		OTHER :	67	1.5	27	1.3		

suring speed and obtaining detailed traffic counts for both directions during periods of low-traffic demand makes the radar-platoon technique a very efficient data-collection method. A 5-min counting cycle length was selected for the Ontario study because it is long enough for statistical aggregation while it remains short enough to reflect any short-term fluctuation.

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Validation of Signalized Intersection Survey Method

A.J. RICHARDSON AND N.R. GRAHAM

The development and validation of a manual survey method for the measurement of performance at signalized intersections are described. The method is easy to use in the field and simply requires that queue lengths and flows be measured at particular times within each cycle of the traffic signals on each approach being surveyed. The output of the program includes frequency distributions and summary statistics for measures of approach delay, stopped delay, stationary queue length, and various definitions of vehicular stops. The validation of the survey method was performed by comparison of survey measurements with measures obtained from a videotape recording of intersection operation. The comparison was performed in two stages. First, results obtained from the field method were compared with results obtained by viewing a videotape of the same traffic stream and extracting the survey data from the videotape. This comparison identified the field observer error in the survey method. Second, the results obtained by using the survey method with the videotape were compared with detailed path-trace information obtained from the same videotape. This comparison identified the theoretical error in the analysis calculations associated with the survey method. The comparison shows that the field survey method produced negligible observer error while the theoretical error in the survey method was quite small and well within the bounds dictated by practical traffic engineering requirements. It is concluded that the survey method is a simple, yet accurate, way of determining signalized intersection performance levels.

The evaluation of signalized intersection performance has long been an issue of concern, a concern that has intensified in recent years with the changing emphasis in urban transportation planning. Tightening budgetary constraints have led to reduced capital expenditure on transportation and have been partly responsible for the present emphasis on transportation system management. Moreover, there has been an increasing need to acquire more knowledge of demand so that the management of it is both publicly acceptable and consistent with an efficient allocation of resources, both privately and socially. To this end, energy conservation, environmental consequences, and equity (in terms of resource allocation, e.g., time savings) have become important concerns. The measurement of intersection performance, for example, should no longer be concerned solely with the motorist but with societal goals as a whole and with the equitable allocation of resources to individual members of society.

Determination of the level of performance of a signalized intersection has application in traffic engineering planning and design, in the study of the effects of physical and operational improvements,