A MASTERS PROJECT

THE CONCEPTS & CONDUCT
OF A
TRAFFIC OPERATIONS STUDY

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PREFACE

This paper addresses the evolution and concepts of Traffic Operation Studies (TOS) within the framework of a medium sized urban municipality. Not only is a description of the basic content of a TOS discussed but as well each of the components of a TOS are described in detail along with the logic for using each of the various components.

This document is intended to serve the general public, politicians and engineers in their deliberations concerning a TOS. Specifically, it serves as a document for the general public to further explain the meaning and purpose of a TOS and the techniques it employs to reduce the problems experienced on existing transportation systems. It serves as a stimulus for the politicians when discussing traffic operational problems within the framework of an urban municipal environment and finally it serves as a guide to engineers when determining the format and content of a TOS.

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1. INTRODUCTION

1.1 BACKGROUND

The evolution of multi-modal transportation systems planning at various levels of government has rather well defined precedents in the highway planning profession. Much of the newly emerging technology in air, rail and transit planning has been a direct result of the techniques and methodologies that were developed by the highway planner and engineer.

In the overall development of transportation systems planning, not only has the highway planning profession contributed in a technical sense but the profession itself has undergone rather dramatic changes in the past 10-15 years. Indicative of the changes has been the rapid evolution of the highway planning profession to one that, today, is more multi-disciplinary in approach and scope than any other profession.

Essential to an understanding of the state of the art of highway planning today is a brief tracing of its evolution and development, in particular, over the past 10-15 years, for it is within this time frame that the real dramatic changes have occurred.

If a review of the requirements and conditions with respect to transportation needs of the 1960's was made, it would become immediately obvious that the issues and resulting challenges were somewhat in balance (1, 2). The goals were simpler and for all practical purposes clearly defined, those being, to keep abreast of, or if possible, a little ahead of the ever increasing patterns of automobile and truck traffic and to eliminate and/or stabilize congestion while providing greater safety. Although these goals and objectives were generally achieved, the highway transportation planning process that emerged in the 1960's was not completely responsive in all respects. As an example, in the

1960's major emphasis was placed on the development of long-range (20-25 year) master plans at the regional scale. No fault can be found with this procedure since this was the nature of the transportation or highway planning process at that point in time. Basically, the process was oriented towards large metropolitan areas and failed to enhance the planning techniques and needs of small communities, in particular, the sub-communities within metropolitan areas. A sophisticated planning process was established that was highly technical and heavily oriented to large data requirements and computer modelling and analysis (3). In many respects, this was justified by the commitment of resources to the construction of new facilities. However, in many areas, this represented an excessive amount of resources being allocated to techniques at the expense of developing appropriate evaluation criteria and more importantly implementation strategies.

The process in itself was heavily oriented to the supply side of transportation with little attention given to the reduction and/or stabilization of demand or the potential of shifting demand to other modes of transportation. In other words, if a facility reached its theoretical capacity and congestion followed, the facility (i.e. roadway) would simply be widened to accommodate the demand. An overriding concern was therefore expressed in terms of facilities needed rather than operating or management techniques required to optimize the use of existing transportation facilities.

The experience of the 1960's combined with rather recent and dramatic challenges such as citizen participation, environmental impact statements, economic considerations, co-ordination of land use and transportation needs, and energy shortages has prompted a new and changing era in the 1970's in which a truly multi-modal and multi-disciplinary transportation planning process has been established at the provincial and municipal levels.

These changes are already being recognized in a great deal of the work currently taking place at the provincial and municipal levels and are reflective of the increasing concern for all modes of transportation and for the need to improve existing facilities (10, 11, 12). For example, the current situation:

1) More emphasis is now placed on incremental and short range planning (2-5 years) as a supplement to long range master planning.
2) Major focus is occurring on the greater use of available techniques to optimize the use of existing transportation facilities.
3) Greater emphasis is being placed on implementing a "family" of transport services (e.g. bus, auto, jitneys, demand responsive transit and intermediate capacity transit).
4) Public participation in the planning process is becoming more and more emphasized.

This paper deals basically with the first two elements of the new transportation planning of today, as described above. Both the short term planning and application of techniques available to optimize the use of existing transportation facilities are applied through a process to assess operating characteristics of a transportation system. This process is called a "Traffic Operations Study" (TOS).

1.2 A TRAFFIC OPERATIONS STUDY

Each of the various components of a TOS and the intricacies associated with them can be found in any general traffic engineering textbook. It has been difficult, however, for engineers over the past few years to truly appreciate where these components actually fit into the true purpose of a TOS. General engineering practice today does not include an account of why TOS's are carried out or how the components relate to each other. In fact, a typical TOS carried out today includes studies of each of these components quite separately from one another and no account is given as to the logic behind the use of each one of the components.

It is the intent of this paper to prepare a detailed account of a TOS in such a manner as to provide a guide of its concepts and components as well as to demonstrate the logic for using each of the various components.

1.2.1 PURPOSE AND SCOPE

The fundamental purpose of a TOS is to review and subsequently provide recommendations to improve the traffic operational characteristics of existing road networks and terminals by providing efficient, free and rapid flow of traffic at nominal cost. At the same time, emphasis must be placed on minimizing the frequency of traffic accidents, injuries and deaths.

More specifically, a TOS is concerned with studying operational problems within an urban environment or framework. Basically this is because of the increasing trend towards urbanization in North America today (4). The transportation problems associated with this trend requires traffic engineers to develop ways and means of coping with these problems. Although urban streets comprise only 14% of the total street system in North America, over 50% of the total vehicle-miles travelled is via the urban road system (5). Urban centres have therefore become the focal point for traffic operational problems and it is here that solutions must be found.

It therefore becomes necessary to determine short term (5-year) solutions to these problems if only as an interim to long range (20-25 year) master plans at the regional level for two reasons; first, because of the economic savings involved and, second, because of the possible severity of the operational problems themselves. It is well appreciated in today's society the inevitability of economic restraint. Therefore it is imperative that maximum efficiency from the existing facilities be achieved within the short term and at nominal cost. The TOS is one means which allows the engineer to study techniques which could satisfactorily accommodate these two concerns.

1.2.2 OBJECTIVES

Traffic Operations Studies are not and never will be the panacea of the urban transportation problem. They do however provide a means to study the impact of techniques which when implemented could well reduce the traffic congestion and unsafe roadway conditions often experienced on existing transportation facilities. They also have the advantage of providing a means to study the application of certain techniques that may allow maintenance of a reasonable level of traffic service on these facilities until such time as the large scale master plans can be both afforded and implemented.

To better appreciate what is involved in a TOS, it is necessary to specify the objectives of a TOS. Generally accepted engineering practice today identifies three basic objectives:

- to determine the effectiveness of all existing traffic control measures and devices
- to determine the nature and magnitude of the present and short term (5-year) future traffic operational problems
- to recommend any improvements which may be initiated immediately and could maximize the level of traffic service on existing facilities and to recommend any other improvements which may be warranted in the short term future to ensure the maintenance of a reasonable level of service on existing facilities and at a reasonable cost.

1.2.3 GENERAL PROCEDURE

The general procedure involved in a TOS is briefly outlined in the flow chart in Figure 1. In order to accomplish the three basic objectives, it is necessary to have available accurate and up-to-date documentation on the study system and all traffic controls and measures. This provides essential information to the traffic engineer to be used to determine the effectiveness of existing and proposed traffic control measures and devices. The most important elements for which information is necessary are:

- Study Limits
- Traffic Control Measures
- Parking Regulations
- Traffic Volumes
- Accident Statistics
- Public Transit System

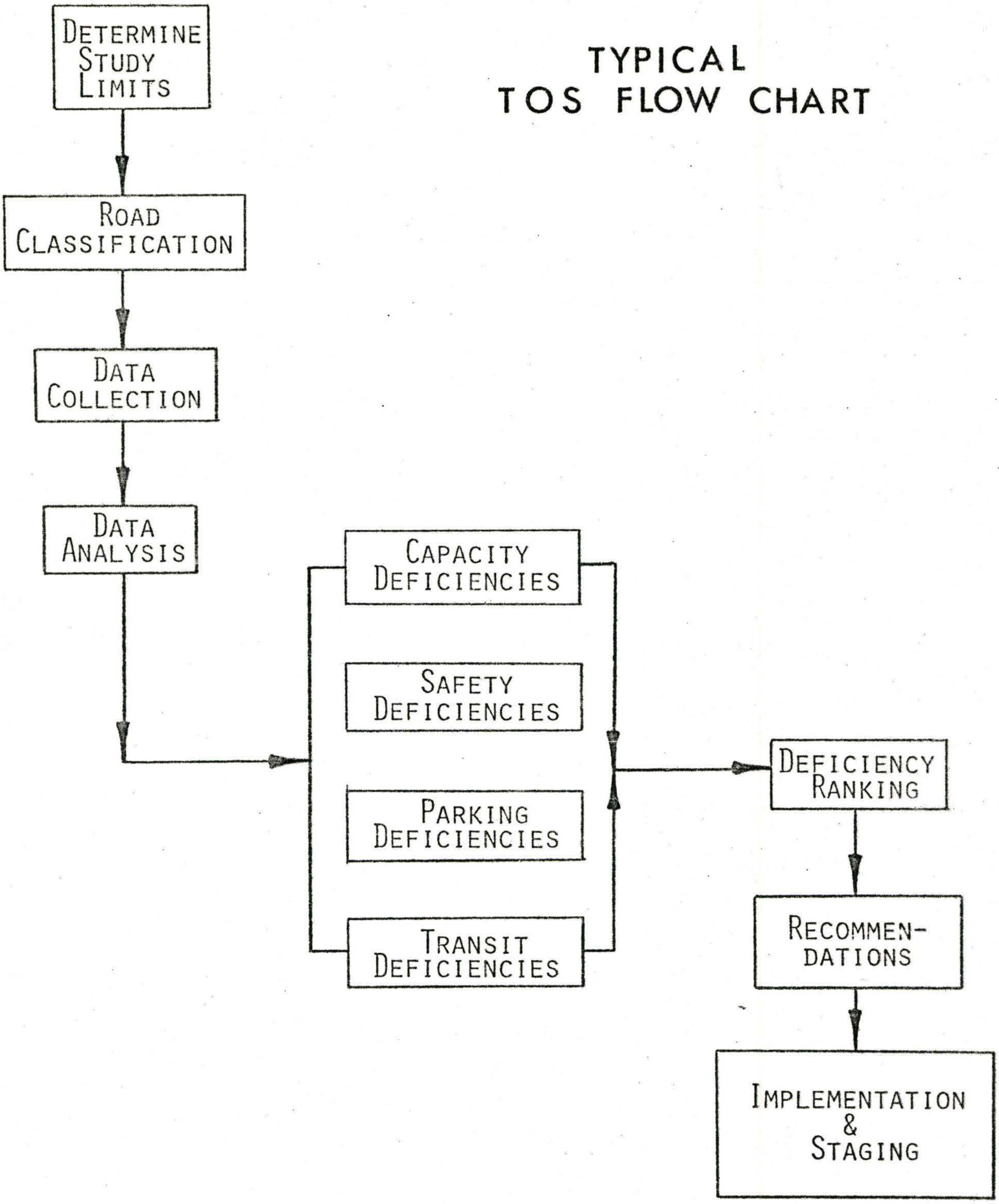
Once the traffic engineer has obtained and reviewed this information, he will have had the opportunity to become more appreciative of possible traffic operational problems that face the municipality under study. A complete and detailed engineering analysis is required prior to a final assessment being formulated as to the effectiveness of existing traffic control devices and measures. The engineering analysis is basically comprised of the following elements:

- Capacity Analysis
- Accident Analysis
- Parking Analysis
- Transit System Analysis

Upon summary of these analyses a detailed assessment of the operational capabilities of the existing street system can be formulated. The analysis is based on established engineering theories and techniques and provides

FIGURE 1

TYPICAL TOS FLOW CHART



the municipality with an accurate technical interpretation of existing traffic operations within their specific study area.

It is also necessary to keep abreast of changing travel patterns and characteristics that are experienced from year to year in the urban area. To prepare for the short term future, existing traffic must be used to forecast a 5-year estimate of traffic volumes. This enables the traffic engineer, upon a detailed analysis of the operational controls to better understand just how effective existing traffic control devices and measures will be when subjected to an increase in travel demand.

This detailed analysis provides the engineer with information that could well prove the obsolescence of existing traffic control devices. Improvements to traffic flow, signalization, parking, etc. may be warranted in order to maintain a reasonable level of traffic service on existing facilities. It also may be deemed necessary to make minor construction improvements to improve traffic operations.

Regardless of the exact alternatives proposed to improve traffic service either now or 5 years in the future, improvements should be such that capital expenditures are minimal and traffic service is at some reasonable level of operation until such time as major improvements are required and the capital available to effect these improvements.

It is also necessary that the TOS be documented in such a manner as to provide the municipality with a complete and detailed account of its traffic operational characteristics at the present time and within its 5 year future. It should also be flexible enough to be easily updated yearly. This benefits the municipality not only from an engineering standpoint but also from an economic and even administrative standpoint. If problem areas and priorities can be readily identified by convenient updating techniques, construction and planning programs could be carried out much easier. This would therefore permit a municipality to achieve its short term objective of maintaining a reasonable level of traffic service on existing facilities while at the same time keeping a perspective of the development of a long term (20 - 25 year) master plan.

The ensuing chapters of this report describe the methodology involved in a TOS and the logic used in each of the various components. Upon completion of the methodology, typical engineering solutions are discussed which will aid the engineer in solving many of the problems identified during the course of the TOS.

2. METHODOLOGY

2.1 INTRODUCTION

The actual methodology of a TOS is a generally accepted one in the field of traffic engineering today. A basic format is used to ensure that all major components or stages are adequately investigated. The five basic stages in a TOS are as follows:

(i) Selection of Study Limits
(ii) Road Classification
(iii) Data Collection
(iv) Data Analysis
(v) Recommendations

Each of the above stages are described in detail in the following sections.

2.2 SELECTION OF STUDY LIMITS

The first step in any TOS involves the identification and classification of the transportation system to be studied. Selection of a system and hence designation of study limits is of prime importance and could be accomplished a number of ways. Study limits are in many cases predetermined by a municipality based on such elements as:

- political motivations
- experience with operating characteristics of the existing road network
- identification of problem areas from background information

If study limits have in fact not been predetermined, certain basic criteria should be used to identify areas that would produce the most useful information to the traffic engineer, information such as:

- operating characteristics of all traffic control devices
- identification of areas of traffic congestion
- identification of areas of inadequate parking, areas of high accident rates, poor transit operations.

The study limits of any TOS should therefore include all major roads carrying relatively high volumes of traffic which in turn form a logical and integrated road system both in present day terms and during the 5-year projection period. For example, a typical TOS in most medium sized urban municipalities could very well involve depending on the capital expenditure allocated to the study, the entire Central Business District (CBD). On the other hand it could also involve a simple grid system comprised of only the major north-south and east-west roadways.

Once the study limits have been identified it becomes necessary to categorize the selected roadways into an orderly grouping according to the type and amount of service they provide. This categorizing or "Road Classification" as it is referred to in engineering terminology, provides the foundation for understanding exactly how a roadway should theoretically function without prior knowledge of its actual detailed operating characteristics.

2.3 ROAD CLASSIFICATION

A road classification consists of an orderly grouping of roads into categories according to the type and amount of service they provide to the motoring public. The principle purposes of a road classification in the context of a TOS are:

(i) to establish logical, integrated categories comprising all roads and streets which provide similar levels of traffic service or operations,

(ii) to group those roadways that require the same quality of construction and maintenance,

(iii) to relate geometric design standards to the roadways in each class for purposes of operational improvements.

There are two basic categories that are associated with road classification:

(i) Urban

(ii) Rural

Only the "urban" category will be discussed in this report since the problems normally studied in a TOS are primarily of an urban nature. The four basic divisions or classes of roadways in the urban category are:

(i) Freeways

(ii) Arterials

(iii) Collectors

(iv) Locals

Also, "freeways" will not be discussed in this report since they are not normally analysed in the same manner as arterials and collectors. Therefore they are not directly related to a TOS in the context of this paper.

Consideration should be given to numerous factors when identifying the classification of certain roadways within the study limits of the TOS. The basic factors to be considered are as follows:

(i) Service Function

(ii) Traffic Volume

(iii) Traffic Flow Characteristics

(iv) Operating Speed

(v) Vehicle Classification

2.3.1 SERVICE FUNCTION

All roadways provide some kind of operational service to traffic. They also provide access to various land uses and in most instances they provide both. For example, arterials provide for movement of traffic between areas of high generation and high attraction in an urban area. They are designed to provide the best quality traffic service in the urban environment within highly developed areas. Access to abutting land use is permitted usually on a limited basis since the prime objective of arterials is fast and convenient movement of people and goods.

Collector streets are similar in nature to arterials with the exception that full access to abutting properties is normally permitted. Parking would also normally be allowed on this type of roadway, unlike arterials, where parking is normally prohibited. The collector roadway can be considered to be the "middleman" of the road network since it collects traffic from the arterial street system and under ideal conditions evenly distributes it to the local street system.

Finally, the purpose of the local streets in relation to service function is to carry only that traffic with an origin or destination along its length. Direct access is also allowed to all abutting properties on a local street with parking normally permitted on one side.

2.3.2 TRAFFIC VOLUMES

Urban arterial streets would normally be expected to accommodate average daily traffic volumes of anywhere from 5,000 to 30,000 vehicles depending on such factors as number of lanes, existence of traffic signals, parking regulations.

Collectors on the other hand would accommodate somewhat lower volumes of traffic. Volumes of approximately 2,000 to 12,000 vehicles per day would not be uncommon for a collector roadway.

Finally, the traffic volumes on local streets are usually of a very minor nature and in most urban municipalities formal traffic counts are not normally carried out so that actual volumes are not readily available. However, the typical local municipal street could very well carry average daily volumes of 200 to 1,000 vehicles.

2.3.3 TRAFFIC FLOW CHARACTERISTICS

The desired characteristics of traffic flow will generally determine the class of a roadway. The traffic flow on arterials is usually uninterrupted except at signalized intersections and crosswalks. Parking, loading and unloading of private as well as commercial vehicles is normally prohibited on arterial roadways. Arterials are also in most instances major transit facilities. In addition since traffic flow on arterial streets is rather significant, pedestrian movements are basically at signalized crossings only.

Collectors provide a somewhat lower level of service since interruptions are not infrequent (i.e. access driveway conflicts, parking, loading and unloading facilities on the street etc.). Pedestrian crosswalks are usually provided as well both midblock and at signalized intersections.

Local streets are characterized by stop, yield or signalized control where they intersect with major streets. Parking is normally permitted on one side or the other and pedestrian movements are usually unrestricted.

2.3.4 OPERATING SPEED

The average operating speed of traffic under off-peak volume conditions will normally vary on roads of the same class depending on pavement condition, intensity of adjacent land development, access to the roadway, vehicle types and traffic operational controls. On the average however, operating speeds for most urban arterial roadways would be approximately 70 to 80 km/h. Collector streets would operate at speeds slightly lower than arterials (approximately 50 to 70 km/h.) with local streets operating at even lower speeds (30 to 50 km/h.)

2.3.5 VEHICLE CLASSIFICATION

The proportion of buses, trucks and passenger cars using a road is generally dependent upon the purpose of the road and is therefore related to the road classification.

All types of vehicular traffic use arterial streets with trucks comprising as much as 20 percent of the total traffic volume. Both express and local buses are generally routed on arterial streets.

Collector streets would carry all types of vehicular traffic in commercial and industrial areas. In residential areas, collectors would carry a low percentage of trucks composed primarily of service vehicles, with the majority of vehicles being private automobiles.

The type of vehicle using local streets normally varies. Residential streets carry predominantly passenger vehicles with a significant number of service vehicles. Industrial local streets carry a very high percentage of trucks. Also, bus operations rarely occur on local residential streets.

In summary therefore knowledge of the street network within predetermined study limits coupled with knowledge of the characteristics of various types of roadways allows the engineer to carry out the road classification for the network under study. This classification sets the stage for understanding just how the study network should theoretically be operating on a qualitative basis. For example, those roadways classified as arterials should be expected to provide a higher level of traffic service to the motoring public than those classified as collectors. In all probability, more emphasis may be placed on the arterial street system when operational improvement priorities are being established after the analysis stage of the TOS. In other words, benefits to be derived from improving an arterial roadway may justify the capital expenditure because of the superior traffic service it provides. However, the same capital expenditure may not be justified for a collector roadway whose traffic service benefit may not be equal to that of the arterial, and, in fact, may even be less.

Road classification therefore provides the engineer with an overview of the study limits and the roadways and their general operating characteristics. It defines roadways as either arterial, collector or local.

Once the classification has been established, as much information as possible should be gathered on those roadways in the system. This information or gathering of data for the TOS is referred to as the Data Collection Stage.

2.4 DATA COLLECTION

At this point in the TOS, the engineer has a basic knowledge of what the study system encompasses with regard to the physical limits and "make-up" of the total system. Classification of roadways enables the engineer to identify those roads which should receive more detailed consideration. In order to properly assess the existing operational characteristics of the system, the engineer must obtain as much information as possible. This information is used to aid in identifying existing problem areas as well as anticipating future areas of concern. Information is basically gathered and summarized in five separate categories:

(i) Traffic Control Measures
(ii) Parking Regulations
(iii) Traffic Volumes
(iv) Accident Statistics
(v) Public Transit System

2.4.1 TRAFFIC CONTROL MEASURES

A complete inventory of all traffic control devices is required to aid in determining their adequacy. Also, any information that is related to the traffic operations of the system should be inventoried and subsequently analysed.

One of the most important and perhaps the most obvious traffic control device that must be inventoried is the traffic control signal or traffic light. The principal function of traffic control signals is to permit crossing streams of traffic to share the same intersection by means of time separation. Information regarding location of traffic signals would normally be made available to the study team by the municipality. If for some reason this is not readily available, it is then necessary that field crews be sent out to physically locate all traffic signals.

Further to the location of traffic signals, it is imperative to take an inventory of the signal timing and phasing. This information would also normally be obtained from the appropriate governing authority. In many cases however, smaller area municipalities may not have the precise timing of the traffic signals and again field crews may be required to actually measure the signal timing.

Also required along with the signal timing and phasing both in peak and in off-peak conditions is the type of traffic signal controllers in use. Due to different operating characteristics of various controllers (i.e. pretimed, traffic actuated, semi-actuated and full actuated), it is imperative that the type of system is known. Details for each type of controller and its unique characteristics can be obtained from basically any traffic engineering text. As with location of traffic signals and phasing, the type of signal and its controller can usually be obtained readily from existing knowledge. More often than not, this is the case and therefore it does not require a field inventory or investigation.

It is also necessary that other traffic control devices in the way of major signs and markings be inventoried. Other than traffic signals, yield signs, stop signs, turning prohibition signs, speed limit signs, crosswalks and lane markings are the primary means of regulating, warning and guiding traffic on all streets and highways. The need for well designed, adequately maintained devices grows in proportion to the density of traffic, speed of operation and the complexity of manoeuvrability areas on the street system. These types of traffic control devices may not, in some smaller municipalities, be as well documented as the traffic signals themselves. It is therefore usually necessary to take an inventory of these devices directly in the field.

2.4.2 PARKING REGULATIONS

Parking regulations are a very important factor that should be considered in any TOS. The supply of, or the lack of, adequate parking facilities can create operational problems. For example, the capacity of a roadway is greatly reduced if parking is allowed on the street. Conflicts arise with people opening car doors which decreases the spacing between vehicles on the travelled portion of the roadway and those in the parking area thus reducing the carrying capability of that roadway.

On-street parking regulations are established by by-law. It is therefore normally possible to obtain much of the parking regulations and prohibitions simply by reviewing the municipality's parking by-laws. If this is not directly accessible, then a field inventory is required at which time measurements are needed to determine such data as:

(i) time restrictions
(ii) physical limits of the prohibitions
(iii) monetary charges (if any)

Similar data must also be collected with regard to the off-street parking lots. It is necessary to determine if the lots are privately owned or municipally owned. The time limits of any meters located on these lots as well as the charges for use of the lots must also be inventoried and documented. The reason for collecting this type of data is basically due to the fact that on-street parking may, in fact, through analysis be identified as creating a capacity deficiency or an unsafe condition on a roadway. This would then require the removal of this parking and its replacement to an off-street parking lot.

It is therefore important to know the capacity of existing off-street parking lots and the availability of these lots to accept additional vehicles.

2.4.3 TRAFFIC VOLUMES

Data is also required on the amount of traffic utilizing the street system under study. There are two typical sources of traffic data used for purposes of analysis in a TOS; the ADT (Average Daily Traffic) and the A.M. and P.M. peak hour volumes. The ADT is in terms of the average daily volume (i.e. 24 hours) of traffic travelling a specific roadway during a year. The peak hour volumes represent the highest volume of traffic experienced on a particular roadway during a specific hour of the day. The ADT and peak hour volumes are used together to determine the adequacy of the roadway's carrying capability. For example, it is not unlikely that a roadway may have an ADT that has been progressively increasing over the past few years and yet the P.M. peak hour volume may have remained constant. This would indicate that the roadway, for all intents and purposes, has reached its capacity. This is because of the fact that normal engineering prcatice uses the P.M. peak hour as a guide in determining the capacity of a roadway. Therefore simply because the ADT increases yearly, it may not, for design purposes mean that the roadway's carrying capacity is being under-utilized.

The volumes of traffic travelling the roadways under study in the TOS can be obtained either from existing data or traffic counts. Two types of counts are normally required to obtain all pertinent information (i.e. volumes, classification, turning movements, etc.); intersection counts and automatic traffic counts between intersections.

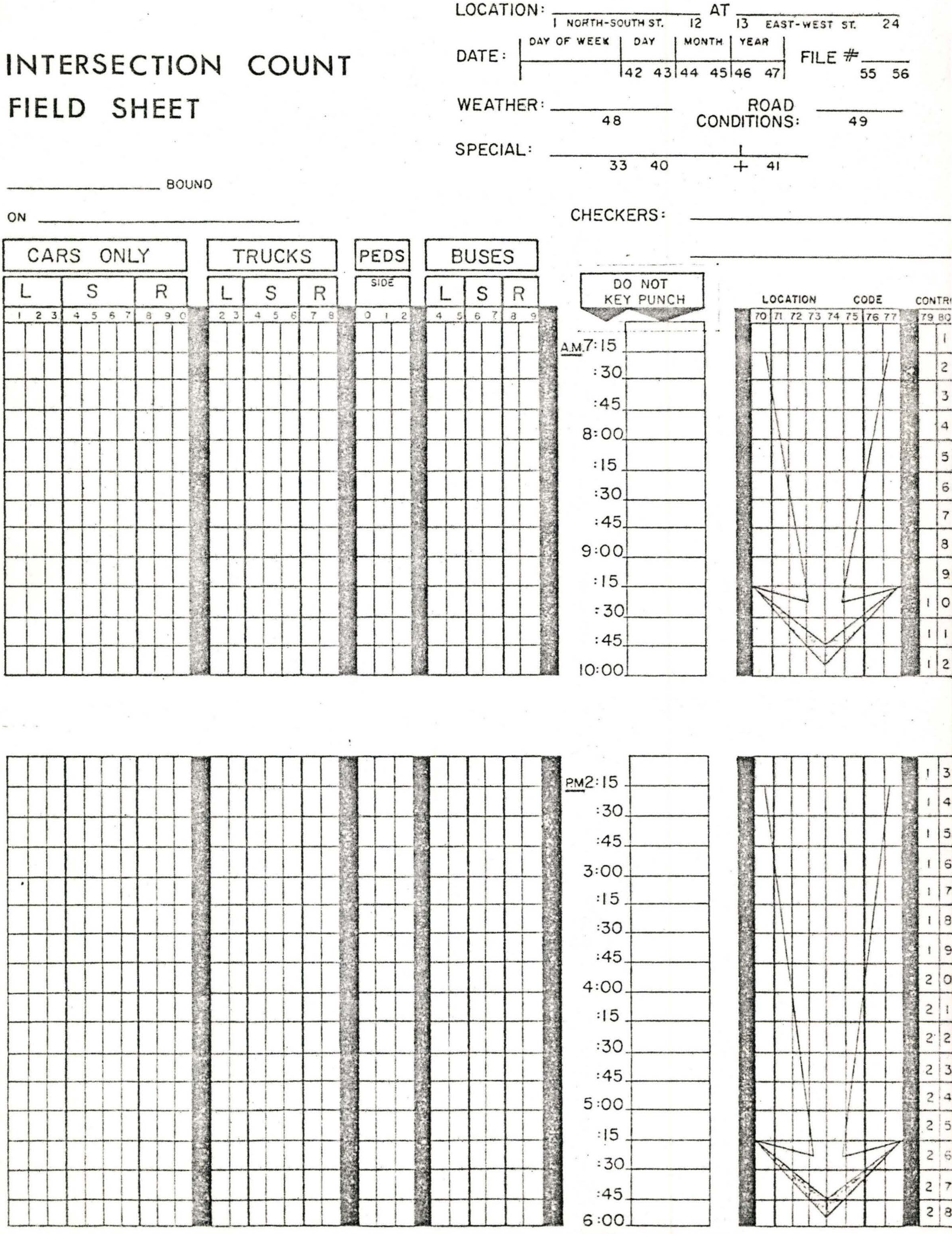
Intersection counts are usually conducted manually. Low volume intersections may be counted by one observer but heavier volumes are usually counted by a team of two or more observers. Each observer counts vehicles entering the intersection from a maximum of two adjacent approaches, records both through and turning movements and classifies the vehicles by type (i.e. passenger vehicle, heavy truck, motorcycle, etc.). Counts are generally totalled every 15 minutes and in most cases include a summary of pedestrian movements. A typical form used to record this type of data is shown in Figure 2. Intersection counts provide quite readily the A.M. and P.M. peak hour volumes.

Counts made between intersections are usually carried out by automatic traffic recorders (ATR's). One ATR is used if only total volumes are desired and two are used if the direction of travel is also to be obtained. Short manual counts made at random peak and off-peak periods can be used to estimate the proportion of vehicle types.

More advanced equipment is available today which provides counts for eight different directional movements and classifications with the use of only one ATR. However, in the simplest ATR, an accumulating register is manually read at desired intervals, perhaps, every 24 hours.and the only data obtained are total counts over the length of time between readings. In one type of ATR a printing mechanism actuated by a clock transfers the count from the register to a paper tape at predetermined intervals. Such totals are commonly printed each 15 minutes and the register automatically resets to zero every hour.

With the availability of traffic volumes obtained from both the manual intersection and 24-hour automatic counts, the analyses of the road system to

FIGURE 2



INTERSECTION COUNT FIELD SHEET

LOCATION: ____________ AT ____________
1 NORTH-SOUTH ST. 12 | 13 EAST-WEST ST. 24

DATE:	DAY OF WEEK	DAY	MONTH	YEAR
		42 43	44 45	46 47

FILE # ______ 55 56

WEATHER: ______ 48

ROAD CONDITIONS: ______ 49

SPECIAL: ______ 33 40 + 41

______ BOUND

ON ______

CHECKERS: ______

CARS ONLY L	CARS ONLY S	CARS ONLY R	TRUCKS L	TRUCKS S	TRUCKS R	PEDS SIDE	BUSES L	BUSES S	BUSES R		DO NOT KEY PUNCH	LOCATION	CODE	CONTR
1 2 3	4 5 6 7	8 9 0	2 3	4 5 6	7 8	0 1 2	4 5	6 7	8 9			70 71 72 73 74 75	76 77	79 80
										A.M. 7:15				1
										:30				2
										:45				3
										8:00				4
										:15				5
										:30				6
										:45				7
										9:00				8
										:15				9
										:30				1 0
										:45				1 1
										10:00				1 2

										P.M. 2:15				1 3
										:30				1 4
										:45				1 5
										3:00				1 6
										:15				1 7
										:30				1 8
										:45				1 9
										4:00				2 0
										:15				2 1
										:30				2 2
										:45				2 3
										5:00				2 4
										:15				2 5
										:30				2 6
										:45				2 7
										6:00				2 8

determine operational adequacy becomes possible.

2.4.4 ACCIDENT STATISTICS

Since a TOS also involves identifying methods to reduce or eliminate hazardous situations, it becomes necessary to identify accident-prone locations. Therefore as much information as possible is required on accidents. It is imperative to identify and obtain information on road location, types of vehicles involved, roadway conditions, etc. Also, knowledge of damage and personal injury sustained is required to help identify the severity of the accident. All of this information is obtained from the police reports and investigations that are carried out. The reports are very extensive and thorough and provide all the necessary data required to analyse and understand accidents. A typical police accident investigation form is shown in Schedule 'A'.

2.4.5 PUBLIC TRANSIT SYSTEM

Finally in order to assess performance of the transit operations system, it is necessary to obtain as much information as possible on transit facilities provided within the study limits. Prior to actual analysis, information regarding the following basic transit system components is required:

(i) location and capacity of terminal facilities
(ii) bus routes
(iii) location of bus stops

This information should be most readily available to the study team from the authority operating the transit system. Information such as bus routes, location of bus stops and schedules are used in the analysis stage to aid in assessing the level of service provided by the transit system. This is discussed in much more detail in the analysis section of this report.

2.4.6 SUMMARY

Upon completion of the preceding data collection, the engineer will have acquired all the background information to carry out the most important stage of the TOS - the Analysis Stage. The traffic control devices and measures have been inventoried, details of these measures have been obtained (i.e. signal timing, controller type), parking regulations and prohibitions have been documented, traffic volumes have been summarized, accident data have been accumulated and detailed background information has been made available on the transit system. This information is then used as input into the analysis stage of the TOS. Without this data, no analysis could be carried out and an assessment of the existing traffic control measures and devices could not be formulated.

2.5 DATA ANALYSIS

The purpose of the analysis stage in a TOS is two-fold; first, to provide the traffic engineer with a technical understanding of operational characteristics within the study system and, second, with the use of predetermined study criteria, to identify specific problem areas.

In identifying problem areas, well-established quantitative methods must be employed to the greatest extent possible to eliminate the possibility of biased judgement. However since it is difficult and often impossible to quantify the seriousness of all problems, sound engineering judgement is required. In most TOS's there exist certain acceptable quantitative engineering criteria that are used to assist in identifying operational problems. Capacity, accident and parking analyses are three of the quantitative and analytical techniques used in present engineering practice to identify traffic operational deficiencies. The Transit System is also analysed in this component of the TOS.

2.5.1 CAPACITY ANALYSIS

The capacity of a transportation facility is the measure of its ability to accommodate a stream of moving vehicles. The maximum service rate or capacity of a facility can be affected by a number of factors - the roadway, vehicle performance characteristics, operational controls and environmental elements. A more useful definition and, perhaps, an easier one to appreciate is the definition of capacity adopted by the Transportation Research Board (6). It defines capacity as the maximum number of vehicles that have a reasonable expectation of passing over a given roadway in a given time period under prevailing roadway and traffic conditions. For example, figures representing typical capacities for various roadway configurations are identified in Table I. When a facility is operating at capacity, the quality of service provided to the user is

TABLE I

HIGHWAY TYPE	CAPACITY (PASSENGER VEHICLES PER HOUR)
TWO OR MORE LANES IN ONE DIRECTION	2,000 AVERAGE PER LANE
TWO LANES IN TWO DIRECTIONS	2,000 TOTAL BOTH DIRECTIONS
THREE LANES IN TWO DIRECTIONS	4,000 TOTAL BOTH DIRECTIONS
ONE LANE FROM A STOPPED CONDITION	1,500

poor in terms of safety, speed and freedom to maneouver. Normally the traffic engineering problem is to determine the "service volume" that can be accommodated and to provide the user an acceptable level of service. Level of service is defined as the qualitative measure that represents the collective factors of speed, travel time, traffic interruptions, freedom to maneouver, safety, driving comfort and convenience and operating costs provided by a transportation facility under a particular volume condition. Table II summarizes the various levels of service used in engineering practice today. These levels of service provide the traffic engineer with a guide as to the acceptability of the operating characteristics of each of the roadways under study.

Although capacity and level of service problems in an urban area are generally associated with signalized intersections, it is imperative to seriously review capacity and level of service of those sections of roadway between signalized intersections. This is a very important factor since not only is signal timing an important element in capacity calculations, but so is road width, side friction along the road due to entranceways, traffic composition, and the existence of parked vehicles. Any one of, or a combination of these, could create "bottlenecks" which could seriously affect roadway capacity upstream of signalized intersections.

Capacity calculations would therefore be carried out at signalized intersections as well as mid-block locations to determine the carrying capability of roadways in the study sytem. The peak hour and ADT volumes obtained in the data collection stage of the TOS would then be used to determine the level of service of each of the existing roadways under study. For example, present traffic engineering practice today uses the volume to capacity ratio (V/C) to determine this. The V/C ratio is a quantitative figure which relates the volume of existing traffic on a roadway (V) to the capacity of that roadway (C). If, for example, the V/C ratio equalled 1.0 the the roadway would be operating at its capacity since the volume presently travelling the roadway would be equal to the theoretical

TABLE II

LEVEL OF SERVICE	TRAFFIC FLOW DESCRIPTION
A	FREE FLOW, ALL DRIVERS FIND FREEDOM OF MOVEMENT
B	STABLE FLOW, MANY DRIVERS BEGIN TO FEEL SOMEWHAT RESTRICTED WITHIN PLATOONS OF VEHICLES
C	STABLE FLOW, OCCASSIONALLY DRIVERS MAY HAVE TO WAIT THROUGH MORE THAN ONE RED SIGNAL INDICATION
D	APPROACHING UNSTABLE FLOW, DELAYS TO APPROACHING VEHICLES MAY BE SUBSTANTIAL FOR SHORT PERIODS OF TIME
E	UNSTABLE FLOW, CAPACITY IS REACHED WITH LONG QUEUES OF VEHICLES WAITING TO ENTER INTERSECTIONS, EXCESSIVE DELAYS
F	FORCED FLOW, JAMMED CONDITIONS WITH INTERSECTION BLOCKAGE

carrying capability of that roadway. Similarly, if the V/C ratio was less than 1.0 then additional traffic could be carried on the roadway since the existing volume would be less than the capacity. Once the V/C ratio has been calculated, it is possible to rank those intersections and roadways by comparing the V/C ratios. This would readily identify locations that are presently experiencing traffic operational difficulties strictly from a capacity standpoint.

Since a TOS involves not only present day traffic operational considerations but also the short term future, it is necessary to repeat the entire capacity analysis utilizing the projected traffic volumes. This would then identify those intersections and roadways that would be deficient with 5 years. This is an extremely important factor. It is quite possible that an intersection may be operating at a very acceptable level of service today; however, the additional traffic volumes that could well be experienced on these roadways within 5 years could create unacceptable traffic conditions. It would then be necessary to provide engineering recommendations for improvements both in present day terms and in the short term future with reference to the capacity of the roadways in the study system.

2.5.2 ACCIDENT ANALYSIS

As indicated previously, a TOS includes amongst other things, studying technqiues of reducing or eliminating hazardous traffic situations. The data collected relating to traffic accidents are used in the analysis stage to determine the effectiveness of existing traffic control devices and roads in the study system. As with capacity analysis, certain criteria must be derived which would provide the engineer with an indication as to the severity of each accident-prone location identified.

The actual analysis for which exist many techniques (7, 8, 9), may well require both macro and micro investigations which use the following criteria:

(i) number of accidents by type

(ii) accident rate

(iii) detailed assessment of accident records

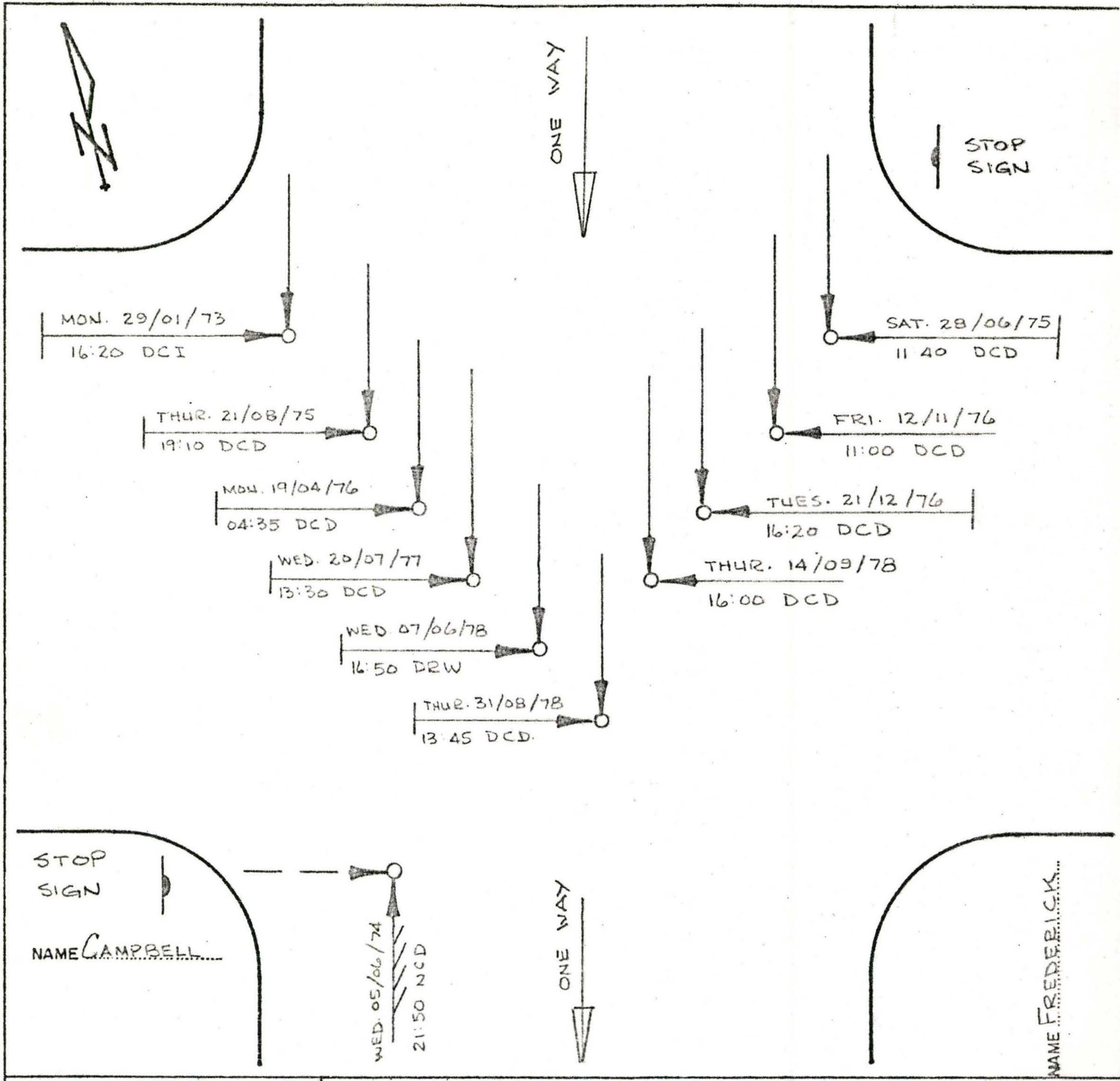
The magnitude and general character of a traffic hazard for a given intersection or roadway for a given year, month or week is measured by the summarization of all accidents by general categories or classes and compared with all other intersections in the study system. This is referred to as macro analysis. This information provides the engineer with a general understanding of the difference between the number of accidents in one section of the system to another. This would normally be summarized simply by the absolute number of accidents occurring which would be easily obtainable from accident data collected earlier.

The macro analysis involves the calculation of not only absolute numbers of accidents, but also calculation of the accident rate. The accident rate is the ratio of the number of accidents occurring at a particular location to the total traffic volume travelling that roadway.

Once the overall accident picture is realized through the macro analysis, the more detailed micro analysis is required to bring the accident records and their meaning into sharp focus for a particular intersection or roadway within the study system.

All of the data required for the micro analysis (i.e. date, location, type, cause, damages, etc.) are obtained from police accident investigation forms. These reports (see Schedule 'A') should be obtained for the past few years in order to determine the general accident trends, if any. This information is then used to prepare collision diagrams. Collision diagrams are schematic drawings of the accident location, showing by conventional symbols, the traffic movements and conflicts involved in accidents at that location. A typical collision diagram is shown in Figure 3. It can be seen from this diagram that certain symbols are used to describe as clearly as possible, the characteristics of the accident.

FIGURE 3
COLLISION DIAGRAM



LEGEND

- MOVING VEHICLE
- REVERSING VEHICLE
- PEDESTRIAN
- PARKED VEHICLE
- FIXED OBJECT(IDENTIFY)
- REAR END COLLISION
- SIDE SWIPE
- OUT OF CONTROL
- FATAL ACCIDENT
- PERSONAL INJURY
- PROPERTY DAMAGE
- DISOBEYED STOP SIGN OR SIGNAL

MON 25/02/74
15:40 DCD
LIGHT CONDITION
WEATHER
ROAD CONDITION

SUMMARY

YEAR	TYPE OF CONTROL	DATE IMPLEMENTED	MONTHS	DAY	NIGHT	TOTAL
19 73	STOP SIGN EB/WB		12	1	–	1
19 74	"		12	–	1	1
19 75	"		12	2	–	2
19 76	"		12	3	–	3
19 77	"		12	1	–	1
19 78	"		10	3	–	3
19						

HAMILTON DEPARTMENT OF TRAFFIC

DATE INITIATED Nov. 22/78 PREP BY MDM

COLLISION DIAGRAM

LOCATION CAMPBELL & FREDERICK

For example, symbols are used to show the following:

1) Direction of travel of each vehicle or pedestrian involved, including non-contact vehicles, so far as they are known; the direction of travel that was originally intended, not that resulting from evasive tactics.

2) Maneouvers intended at the location but not those made as evasive tactics.

3) Special conditions, for example, wet driving surfaces.

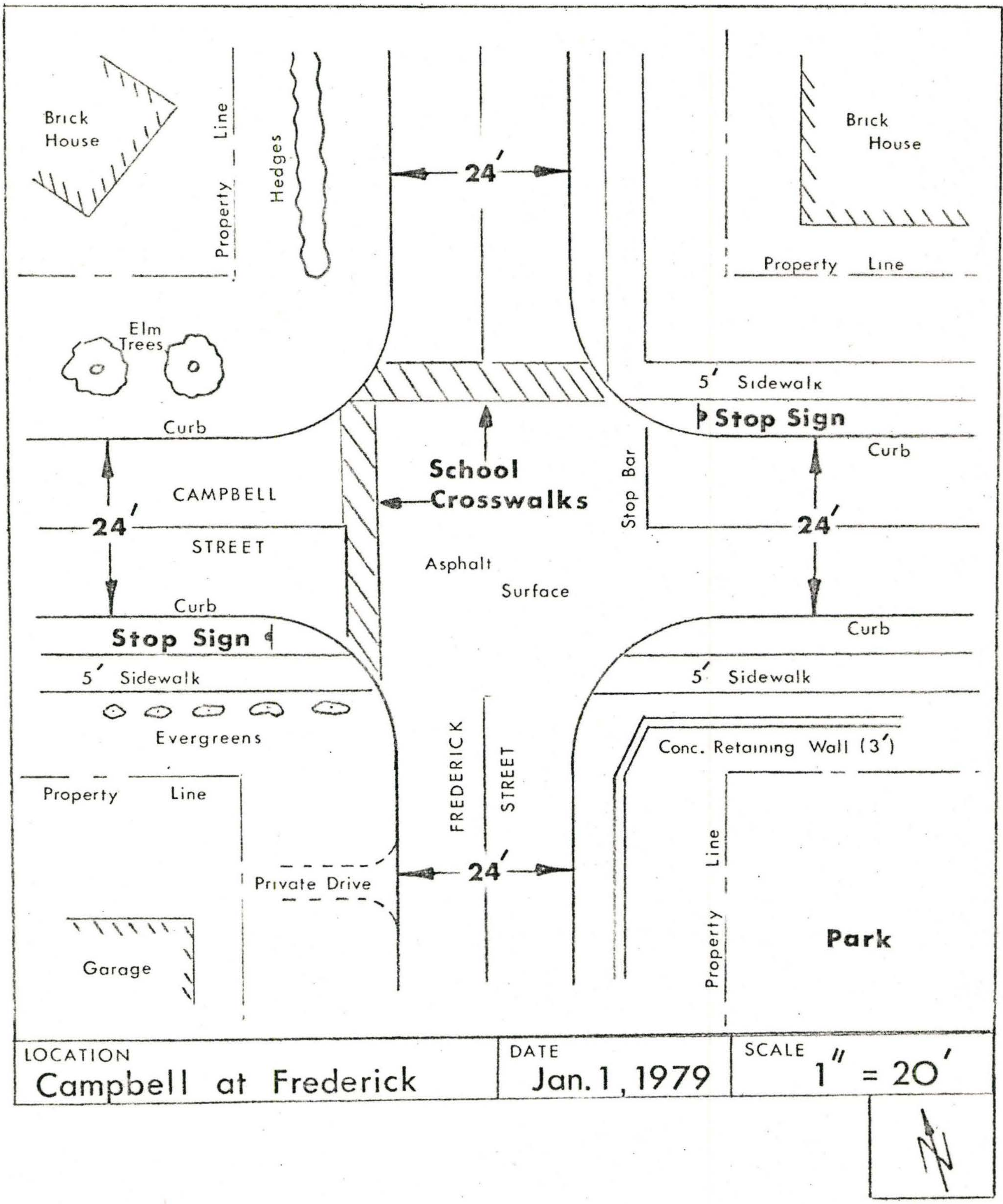
The study of these collision diagrams consist mainly of identifying accident patterns; that is, a number of accidents having common circumstances. Sometimes these are conspicuous as, for example, a large number of accidents involving left turns; in other cases, they are obscure, as when accidents occur most commonly under special lighting or road surface conditions. Sometimes there are two or more patterns or different patterns at different times of the day or week. No matter what the apparent cause, the collision diagrams provide an easy means of identifying the actual causes.

The next step in the micro analysis is the preparation of a condition diagram or inventory sketch. The condition diagram shown in Figure 4 is a scale drawing showing layout, widths and grades of intersecting roadways, locations of any obstacles which may obscure the vision of the drive, and traffic control devices and parking requirements.

Finally, a detailed review is required of the accident reports, collision diagrams and condition diagrams to determine the causes of the accidents. It is here that the engineer must make a judgement decision. No technique exists that will give the engineer the direct answer to a specific problem. The engineer must assess the situation with all facts obtained and use this information to select the most appropriate treatment for the location with consideration given to available funds and relative importance.

FIGURE 4

CONDITION DIAGRAM



LOCATION Campbell at Frederick

DATE Jan. 1, 1979

SCALE 1" = 20'

2.5.3 PARKING ANALYSIS

The problem of parking is very important in today's automobile oriented cities. Much of the congestion is caused by inadequate parking facilities. This can be attributed to the fact that in urban areas, population and motor vehicle ownership and usage have increased significantly in recent years. Frequently, the number of parking spaces has not kept pace with this growth. The parking problem is especially important because it affects everyone, not only individual drivers but also downtown merchants and businessmen, transit operators and the trucking industry.

More specifically and in the context of this report, parking problems can be directly related to operational characteristics of transportation facilities. On-street parking can severely restrict the smooth and safe operation of a roadway for two reasons; first, the existence of parking on a major roadway eliminates the use of one full lane for not only passenger cars, but also transit vehicles. On a four lane, two directional roadway, this basically reduces the capacity of that roadway by approximately 50%. Second, the existence of parking on roadways can create safety hazards. The opening of car doors into moving streams of traffic and the possibility of small children and elderly citizens walking from between parked cars poses serious safety concerns to the traffic engineer.

It is for these reasons that parking studies form an integral part of a TOS. The purpose of this section is to describe the methodology of conducting typical parking studies within the framework of a TOS.

There are basically two types of parking studies carried out in a TOS:

(i) On-street parking

(ii) Off-street parking

Unlike capacity analysis and accident analysis where all required background information is obtained in the data collection stage, only a small portion of the parking data is collected at that time. This is because the analysis stage is basically an inventory in itself. This is true for both the on-street parking and the off-street parking studies.

(I) ON-STREET PARKING STUDY

The typical on-street parking study in a TOS is made to determine the number, duration and location, by vehicle type, of parking activities within the study system. These studies are useful in determining locations of heavy and light parking and the usage of existing facilities.

Each designated block within the study system is given a number which is placed on a field sheet. Numbering should correspond to that used in the parking inventory obtained in the data collection stage of the TOS. A typical field sheet is shown in Figure 5.

The time and length of the study are also important. Unless specific problems are identified prior to the actual study, it is necessary that the study be carried out under normal circumstances. For example, days immediately preceding or following holidays, special shopping days, or days when stores' operating hours are different than usual, are not considered as normal days. The typical hours used for this type of study are between 8:00 a.m. and 6:00 p.m. on a normal weekday.

Field crews are then sent out each with their own specific area to study, at which time the parking activity in that area is inventoried and summarized. It is a simple matter of identifying the license plate number of the parked vehicles and the location and time of the observation. Recording license plate numbers identifies the length of time (within established intervals) that vehicles are parking in a certain parking space or meter. This provides the average turnover of vehicles within the study system at a particular location. This is repeated for the entire study time limit at acceptable intervals. The intervals are usually established on a 15 to 30 minute basis depending on the size of the

FIGURE 5
ON-STREET PARKING STUDY FIELD SHEET

DATE ______________ STREET ______________ SIDE (LOT) ______________

BETWEEN ______________ AND ______________ ZONE ______________

TYPE(S) OF SPACE(S) ______________ BLOCK ______________

______________ FACE ______________

STUDY CONDUCTED FROM ________ A.M. TO ________ P.M.

TIME PERIOD	NO. OF CARS PARKED LEGALLY	ILLEGALLY PARKED	TOTAL	%	CAR MINUTES
20 min. or less					
40 min. or less					
1 hour or less					
1 hr. 20 min. or less					
1 hr. 40 min. or less					
2 hrs. or less					
2 hrs 20 min. or less					
2 hrs. 40 min. or less					
3 hrs. or less					
3hrs. 20 min. or less					
3hrs. 40 min. or less					
4 hrs. or less					
Over 4 hrs.					
TOTAL					
		AVERAGE DURATION			

MAX. TOTAL ACCUM: ______________ VEHICLES AT ______________

LEGAL SPACES ______________ PEAK % USAGE ______________

AVG. TOTAL VEH. PARKED ______________ AVERAGE % USAGE ______________

RATE OF TURNOVER (Total legal veh./legal spaces) ______________

LEGAL SPACE HOURS AVAILABLE ______________

TOTAL NO. OF CARS PARKED

9:00	9:20	9:40	10:00	10:20	10:40	11:00	11:20	11:40	12:0
12:20	12:40	1:00	1:20	1:40	2:00	2:20	2:40	3:00	3:20
3:40	4:00	4:20	4:40	5:00	5:20	5:40	6:00	6:20	6:40

study area and manpower available.

The information obtained from the on-street parking study provides the engineer with a detailed knowledge of existing parking conditions on the streets within the study system. Problem areas can be easily pointed out and sound engineering recommendations made to help alleviate the problems.

(II) OFF-STREET PARKING STUDY

There are several methods of carrying out an off-street parking study. Field observers can simply go through each lot or garage in the study area at regular intervals, recording license plate numbers as with the on-street parking study. Care must be taken to simplify the recording in order to compare license plate numbers during the summarizing process. The intervals between trips, if the off-street study is made part of the on-street study, should be the same as in the on-street study.

The number of vehicles and the corresponding license plate numbers of vehicles in the lot or garage at the beginning of the study and also at the end of the study should be noted. The first count is essential to calculating accumulations at various periods of the day and the count at the conclusion of the study serves as a check on the calculated accumulation as evolved in the analysis. A typical field sheet used for such a study is shown in Figure 6.

The results obtained in the on-street and off-street parking studies are used together with the capacity and accident analyses. All three are used to arrive at solutions to the problems identified in the analysis stage of the TOS.

For example, if the capacity and safety of a roadway is in jeopardy due to existing parking on that roadway, then removal of that on-street parking would significantly improve both the capacity and safety conditions. However, if the parking is removed from the street, demand for those parking spaces still exists. The off-street parking study produces information identifying usage and availability

FIGURE 6
OFF-STREET PARKING STUDY
FIELD SHEET

PARKING ACTIVITY SURVEY TEN MINUTE PERIODS

DATE ________ OBSERVER ________ STREET ________ SIDE (LOT) ________ FROM ________ TO ________

ZONE	BLOCK	FACE	SPACE		9:30	9:40	9:50	10:00	10:10	10:20	10:30	10:40	10:50	11:00	11:10	11:20	11:30	11:40	11:50	12:00	12:10	12:20	12:30	12:40	12:50	1:00	1:10	1:20
			CODE	TYPE	1:30	1:40	1:50	2:00	2:10	2:20	2:30	2:40	2:50	3:00	3:10	3:20	3:30	3:40	3:50	4:00	4:10	4:20	4:30	4:40	4:50	5:00	5:10	5:20

RECORD ONLY LAST 3 DIGITS OF LICENCE. USE CHECK MARKS INSTEAD OF REPEATING NUMBERS. UNDERLINE NUMBERS OF COMMERCIAL VEHICLES. CROWD NUMBER IN & MARK D.P. FOR DOUBLE PARKERS. USE ASTERISK (*) TO DENOTE TWO VEHICLES IN ONE TIME PERIOD.

of off-street lots to accommodate additional demand. If on-street spaces can be accommodated in off-street lots, the problem is alleviated. If, however, the demand exceeds the capacity, then additional off-street parking lots would have to be constructed.

2.5.4 THE TRANSIT SYSTEM ANALYSIS

The presence of transit service in urban metropolitan areas presents an opportunity for the traffic engineer to achieve an optimum balance from an overall community standpoint in the use of existing streets and highways and those new facilities obtainable in the foreseeable future. Analysis of the transit service consequently plays an important role in a TOS. Many types of analytical studies are available to the traffic engineer to assess the operational characteristics of the transit service in the study system of a TOS, but the most general technique used is the Transit Speed and Delay Study.

(I) THE TRANSIT SPEED AND DELAY STUDY

This study involves recording the causes, locations and amounts of delay to buses operating on a route as well as the number and cause of slow starts, slow stops and slowdowns. The overall transit speed along the route is also revealed. The study is used to indicate where delays, such as parking and improper signal timing exists to indicate which transit lines require additional study and improvement, such as skip-stops and turn-backs, to measure conditions before and after traffic improvements and to assist transit authorities in making or improving schedules of operation.

The first step in carrying out such a study is to determine which bus routes should be analysed. Basically, all bus lines carrying heavy loads and experiencing difficulty in maintaining schedules should be studied. This information would be obtained not only from the traffic volumes collected but also through discussions with the transit operating authority.

The actual study is carried out by field observers who ride the transit vehicles normally during periods of major traffic movement when the maximum number of shoppers and workers are riding the buses. The same transit line would be reviewed on two or three weekdays to develop data representing average peak traffic conditions. The observer uses a field sheet (a typical Transit Speed and Delay Sheet as shown in Figure 7) to observe the starting time of the trip, the location and the duration and cause of delay. Symbols would normally be used to show causes of delay, such as "P" for passenger loading, "S", for delay at traffic signal, "LT" for left turns of other traffic, etc.

Each delay in movement which is not a stop, is noted on the right-half of the field sheet by writing the cause for each slow start, slow stop or slowdown. At the end of each one-way trip, the time is recorded and a new field sheet started for the following trip. The total number of seconds stopped would then be entered at the bottom of the field sheet as well as the total number of slow starts, slow stops and slowdowns.

The final step is then to summarize all trips on each of the transit lines for the duration of the study. This period could extend for 1 or 2 hours. To aid in this summary, a special summary sheet such as that in Figure 8 could be used. The length of route could be obtained from the transit authority by measuring the route on a map or by measuring it in the field. Referring to Figure 8, "Vehicle No." and "One-way Trip No." would be copied from the field sheet. The figure under "Overall Trip Time" would be taken from the times entered at the top of the field sheet. The average trip speed could then be calculated by dividing the length of route in kilometers by the overall trip time in hours. Finally, at the bottom of the summary sheet, the various averaged figures would be entered giving an overall review of the transit line.

FIGURE 7

TRANSIT SPEED AND DELAY

FIELD SHEET

VEHICLE NO. ______________ LINE ______________________________ DIRECTION ____________

ONE WAY TRIP NO. __________ TRIP STARTED TIME ____ AM PM AT ____________________ (LOCATION)

ENDED TIME ______ AM PM AT ____________________________ WEATHER ______________

LOCATION	SECONDS STOPPED	CAUSE	CAUSE OF SLOW START	CAUSE OF SLOW STOP	CAUSE OF SLOW DOWN
TOTALS		☒			

SYMBOLS OF DELAY CAUSE P-PASSENGER LOADING S-TRAFFIC SIGNAL SS-STOP SIGN
PK-PARKED CARS DP-DOUBLE PARKING PED-PEDESTRIANS LT-LEFT TURNS
T-GENERAL CONGESTION KT-INTENTIONALLY KILLED TIME

FIGURE 8

TRANSIT SPEED AND DELAY

SUMMARY SHEET

LINE ____________________ DATE ____________

LENGTH(ONE-WAY) ____________ TIME ________ AM PM TO ________ AM PM

Vehicle No.	One Way Trip No.	Overall Trip Time	Average Trip Speed	Total Time Stopped	Number Of			
					Stops	Slow Starts	Slow Stops	Slow Downs
AVERAGE								

The Travel Speed and Delay Study will provide the engineer with data on the overall speed for each bus route, the amount and number of delays, and the number of slow starts, etc. for each transit line or bus route. These data are useful in concluding which routes are either in need of remedial action or further study. Thus, a review of the analysis would indicate the need for remedial measures or the need for more long term solutions.

2.6 SUMMARY OF THE DATA ANALYSIS

In summary, the analysis stage of the TOS will have identified a multitude of operational problems. The capacity analysis will have outlined those intersections whose carrying capability is either presently at its peak or will be within 5 years. It will have identified which intersections or roadways within the study area or system are more severe than others. It will have therefore identified specific engineering problems for which solutions must be found.

The accident analysis will have pointed out unsafe traffic conditions at various locations within the study system. These problems have been well defined and documented and priorities have been set with regard to the severity of and the location of these accident-prone areas. Again, the traffic engineer must provide sound engineering recommendations to help alleviate these unsafe traffic conditions.

The parking analysis will have defined areas within the study system which are deficient in parking spaces. This problem too must be solved.

Finally, the transit system anaysis will have provided the engineer with a basic understanding of the operational deficiencies within the transit system and why these deficiencies are occurring.

The traffic engineer at this stage should fully appreciate and understand the traffic operational problems identified. It is here that the engineer's experience and expertise is utilized to arrive at sound engineering recommendations.

It is also important that these recommendations for improvements to the study system be such that capital expenditure is nominal. This would be in keeping with the true purpose of the TOS to have reviewed and subsequently provided recommendations to improve traffic operations of existing road networks and terminals by providing efficient, free and rapid flow of traffic at nominal cost.

This therefore brings the engineer to the final stage in the TOS, at which time engineering recommendations are made to improve traffic operations within the study system. This final stage is generally referred to as the Recommendation Stage.

3. RECOMMENDATIONS STAGE

The traditional approach used to arrive at recommendations in a TOS is to review and understand the traffic operational problems identified in the analysis stage. In dealing with any complex problems such as those associated with traffic engineering, there is a tendency to immediately post alternative solutions or recommendations without first establishing the exact nature and scope of the problems. Careful thought and an adequate understanding of problems identified in the analysis stage is mandatory. The manner in which a problem is formulated gives guidance and direction to its solution and dictates the results that are achieved.

The engineer should distinguish between the cause of a problem and the symptoms or phenomena that are the results of an underlying cause. Frequently, solutions are directed to apparent symptoms of conflicts or difficulties and the basic cause is overlooked. For example, traffic congestion at an intersection might be considered a symptom of a problem instead of a problem. In this case, congestion is a phenomena that is seen and measured. The cause of the congestion might, however, be associated with inadequate zoning controls, inadequate road design, the existence of parking, poor signal timing, etc. The traffic engineer should definitely recognize that the problem can be much broader than the fact that traffic demand is greater than capacity. This is why it is extremely important in the recommendation stage that the implications of each of the recommendations are known in relation to each of the four elements of the analysis stage (i.e. capacity, parking, accidents and the public transit system).

For example, if it is identified in the analysis stage that a particular section of roadway is operating at capacity because of parking on one full lane of the roadway, then it would seem immediately obvious that parking should be removed. An initial review of this recommendation would suggest that the solution is a positive one. The capacity of the roadway would be increased, the potential safety hazard eliminated and the operations of the transit system improved. However, the potential negative impact is related to the parking itself. By removing parking on the roadway, a new demand for parking elsewhere is created. This may mean that additional off-street parking lots would have to be constructed if the parking analysis has indicated that additional parking spaces are not available in the existing off-street lots.

This brings out an extremely important consideration. It may well be that no one particular solution exists for a specific problem since a new problem could easily arise from the proposed solution. Therefore it is necessary to provide the best engineering solution which will benefit the study area in terms of solving a problem for the general good of the transportation system as opposed to solving a problem for a specific area within the system.

Once the actual problems have been definitely identified and a general review is made, the recommendations that are made are basically categorized under two areas:

(i) immediate improvements
(ii) short term improvements

3.1 IMMEDIATE IMPROVEMENTS

Immediate improvements are those which would provide solutions that when implemented would satisfy present traffic operational needs of the study system. They would also be improvements which could be carried out with a nominal capital expenditure.

Typical immediate improvements to transportation systems would be categorized under the four basic analyses carried out in the analysis stage of the TOS (i.e. capacity, parking, accident and transit analysis). Listed below are examples of the types of recommendations made in relation to each of the analyses to immediately improve traffic operations of a study system:

(i) To Improve Capacity
  - prohibition of left turns at major intersections during peak hours of traffic movement
  - restriction of parking in the vicinity of an intersection
  - adjustment of signal timing
  - painting of pavement markings

(ii) To Improve Parking
  - provision of additional off-street parking lots
  - provision of more on-street parking meters on side streets
  - design improvements to off-street lots to increase capacity

(iii) To Reduce Accidents
  - erection of stop signs
  - creation of pedestrian crosswalks
  - removal of trees or shrubs to improve corner visibility at intersections

(iv) To Improve Transit Operations
  - establishment of "No Parking" zones at bus stops
  - bus stop relocation
  - reduction in the number of bus stops

The above list is far from being exhaustive but it does indicate the general types of immediate solutions and hence recommendations which would be made at the conclusion of a TOS. These recommendations are not significantly costly in nature and would therefore satisfy the immediate operational needs of the study system without a large capital expenditure.

3.2 SHORT TERM IMPROVEMENTS

As well as investigating existing operational problems, short term future operational problems must also be dealt with. To this end, future problems are identified, solutions are formulated and recommendations made. Also to keep within the framework and purpose of a TOS, these short term recommendations should be such that capital expenditures are nominal. More often than not, however, these solutions require a higher capital expenditure than the immediate solutions. This is because sections of roadway or intersections that would be presently operating close to capacity could very well, within 5 years, experience severe operational characteristics that may only be solved with reconstruction, widening, signal installation and other such improvements.

Listed below are examples of the types of recommendations made in a TOS in relation to each of the various anayses carried out which would provide improvements to the operations of the study system for the short term:

(i) To Improve Capacity

- widening of intersection approaches
- installation of traffic signals
- construction of a new roadway

(ii) To Improve Parking

- construction of new parking lots or parking garages
- initiate a detailed review of the downtown parking conditions

(iii) To Reduce Accidents

- construction of medians to separate heavy vehicular traffic flow
- installation of traffic signals
- construction of pedestrian cross-overs

(iv) To Improve Transit Operations

- construction or designation of exclusive bus lanes
- signal pre-emption system to give buses priority at signalized intersections
- purchasing of additional buses

Again, this list is not an exhaustive one, but it does provide for a general understanding of the types of improvements that are recommended as an end result of a TOS.

The Recommendations Stage of a TOS is the end result of usually many months of detailed engineering analysis of traffic operational problems of an area municipality. It is this stage where the final outcome is one which can be appreciated by not only the traffic engineer but also decision makers in the political arena. Definitive solutions which will help in reducing the severity of traffic problems are presented. It is here where a true appreciation of the convenience and usefulness of a TOS becomes apparent. The decision makers have been made aware, from a traffic engineering standpoint, of what the actual problems are that are creating their everyday traffic nuisance. Further, from a layman's point of view, they are then presented with solutions to these problems - solutions which they not only appreciate and understand, but solutions that they may very well see implemented on existing streets within a very short time period.

4. SUMMARY AND CONCLUSIONS

The scope of this paper was to produce a methodology that will enable the local transportation planner and traffic engineer to systematically plan and implement traffic engineering and traffic control improvements through the assistance of a TOS. But perhaps more importantly, this report will provide local officials with the methodology for performing a systematic analysis of their total metropolitan area and controlling and operating their system in that area in a manner that will ensure it is used to its fullest potential.

It has not been suggested in this report that the TOS is the "be all and end all" of the transportation planning process. It has, however, suggested that the TOS is one process that, when utilized, allows the engineer to study techniques and their effect in optimizing existing streets and transportation facilities with nominal capital expenditure.

The TOS serves only as an interim method of assessing techniques and analyses to improve existing systems. It is imperative that the long range master planning still be utilized to provide overall, large scale, transportation system proposals. The TOS, however, has been shown to be used as an immediate and short term process to assist in solving traffic problems. The master plans, however, provide much more general solutions that will, in the long term, satisfy the complete needs of the ever expanding urban centres. Until such time, however, the TOS is a process that should be made available to urban municipalities by traffic engineers simply to provide temporary relief to the operational problems that do exist.

SCHEDULE `A´

POLICE ACCIDENT INVESTIGATION FORM

Ontario

MOTOR VEHICLE ACCIDENT REPORT

NAME OF SUBMITTING POLICEFORCE

REPORT COMPLETED ☐

NAME OF INVESTIGATING OFFICER | NO. | DIV/STAT/DET

ACCIDENT NUMBER | PAGE | OF

DATE OF ACCIDENT | DAY | TIME OF ACCIDENT

TIME OFFICER ARRIVED OR AGENCY ACCIDENT REPORTED TO

LOCATION

ROAD 1 STREET, ROAD, HIGHWAY, ETC. | CODE

HOUSE NO. OR DISTANCE ☐ METRES OR ☐ KILOMETRES ☐ N ☐ S ☐ E ☐ W OF

ROAD 2 INTERSECTION KEYPOINT PATROL AREA OR OTHER REFERENCE | CODE

MUNICIPALITY | COUNTY, DISTRICT OR REG. MUNIC.

ROAD JURISDICTION

- ☐ 1 MUNICIPAL (EXCL. TP. RD.)
- ☐ 2 PROVINCIAL HIGHWAY
- ☐ 3 TOWNSHIP
- ☐ 4 COUNTY OR DISTRICT
- ☐ 5 REGIONAL MUN.
- ☐ 6 PRIVATE PROPERTY
- ☐ 7 OTHER

CLASSIFICATION OF ACCIDENT

- ☐ 1 FATAL INJURY
- ☐ 2 NON-FATAL INJURY
- ☐ 3 PD ONLY
- ☐ 4 NON-REPORTABLE

DRIVER 1

☐ INDIRECTLY INVOLVED

DRIVER (SURNAME FIRST) | CODE | VEHICLE MAKE | YEAR | COLOUR | BODY STYLE | PERMIT NUMBER | YEAR | PROV/STATE

ADDRESS | TELEPHONE NO. | OWNER (SURNAME FIRST) | TELEPHONE NO.

POSTAL CODE | ADDRESS | NUMBER OF OCCUPANTS IN VEHICLE

LIC'D TO DRIVE ☐ YES ☐ NO | DRIVER LICENCE NUMBER | INSURED ☐ YES ☐ NO | INSURANCE COMPANY AND POLICY NUMBER | OR PAID U.M.V.F. ☐

PROV/STATE | CLASS | COND. | DATE OF BIRTH | SEX | DR. EXP. | DESCRIBE TYPE OF VEHICLE OR COMBINATION OF VEHICLES | ☐☐☐ CODE

DRIVER 2

☐ INDIRECTLY INVOLVED

DRIVER (SURNAME FIRST) | CODE | VEHICLE MAKE | YEAR | COLOUR | BODY STYLE | PERMIT NUMBER | YEAR | PROV/STATE

ADDRESS | TELEPHONE NO. | OWNER (SURNAME FIRST) | TELEPHONE NO.

POSTAL CODE | ADDRESS | NUMBER OF OCCUPANTS IN VEHICLE

LIC'D TO DRIVE ☐ YES ☐ NO | DRIVER LICENCE NUMBER | INSURED ☐ YES ☐ NO | INSURANCE COMPANY AND POLICY NUMBER | OR PAID U.M.V.F. ☐

PROV/STATE | CLASS | COND. | DR. EXP. | DATE OF BIRTH | SEX | DR.EXP. | DESCRIBE TYPE OF VEHICLE OR COMBINATION OF VEHICLES | ☐☐☐ CODE

INVESTIGATING OFFICER'S DESCRIPTION OF ACCIDENT

TRAFFIC CONTROL

OPERATIVE

YES NO

- ☐ ☐ 1 TRAFFIC SIGNAL
- ☐ ☐ 2 STOP SIGN
- ☐ ☐ 3 YIELD SIGN
- ☐ 4 PEDESTRIAN CROSSOVER
- ☐ 5 POLICE CONTROL
- ☐ 6 SCHOOL GUARD
- ☐ 7 SCHOOL BUS
- ☐ 8 NO CONTROL
- ☐ 9 OTHER (SPECIFY)

VISIBILITY

- ☐ 1 CLEAR
- ☐ 2 RAIN
- ☐ 3 SNOW, SLEET
- ☐ 4 FOG, MIST, SMOKE, DUST

LIGHT

- ☐ 1 DAYLIGHT
- ☐ 2 DAWN
- ☐ 3 DUSK
- ☐ 4 DARK

DIAGRAM OF ACCIDENT, INCLUDE ALL MEASUREMENTS. USE SOLID LINE FOR DIRECTION TO IMPACT, BROKEN LINE AFTER.

INDICATE NORTH BY ARROW ○

DESCRIBE DAMAGE TO VEHICLE 1* | IMPACT 1 ☐ 2 ☐ | DAMAGE EST. $

DESCRIBE DAMAGE TO VEHICLE 2* | IMPACT 1 ☐ 2 ☐ | DAMAGE EST. $

DESCRIBE DAMAGE TO OTHER PROPERTY

PERSON AND/OR AGENCY ADVISED | DAMAGE EST. $

EJECTION

1 YES
2 PARTIAL
3 NO

SAFETY EQUIPMENT USE

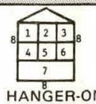
1 YES
2 PELVIC BELT ONLY
3 NO
4 UNKNOWN

SAFETY EQUIPMENT FITTED

0 NONE
1 PELVIC BELT
2 TORSO BELT
3 PELVIC & TORSO BELT
4 CHILD RESTRAINT
5 HELMET
6 UNKNOWN
7 OTHER

INJURIES

0 NONE
1 MINIMAL
2 MINOR
3 MAJOR
4 FATAL
5 DROWNING
6 ASPHYXIATION



8 HANGER-ON
9 PEDESTRIAN

VEHICLE NUMBER	NAME (SURNAME FIRST) AND ADDRESS (INVOLVED PERSONS)	TELEPHONE NO.	AGE	SEX	POSITION	INJURIES	SAFETY EQUIPMENT FITTED	SAFETY EQUIPMENT USE	EJECTION
	1								
	2								
	3								
	4								
	5								

UNIT 1

INDEPEDENT WITNESSES NAME (SURNAME FIRST) AND ADDRESS

1
2
3

ACCIDENT NO. | PAGE | OF

EMERGENCY EQUIPMENT IN ATTENDANCE | CALLED BY

SERVICES PERFORMED

ROAD LOCATION

- ☐ 1 NON-INTERSECTION
- ☐ 2 INTERSECTION RELATED
- ☐ 3 IN INTERSECTION
- ☐ 4 AT/NEAR PRIVATE DRIVE
- ☐ 5 AT RAILWAY CROSSING
- ☐ 6 UNDERPASS OR TUNNEL
- ☐ 7 OVERPASS OR BRIDGE
- ☐ 8 OTHER (SPECIFY)

ROAD SURFACE CONDITION

1 2

- ☐ ☐ 1 DRY
- ☐ ☐ 2 WET
- ☐ ☐ 3 LOOSE SNOW
- ☐ ☐ 4 SLUSH
- ☐ ☐ 5 PACKED SNOW
- ☐ ☐ 6 ICE
- ☐ ☐ 7 MUD
- ☐ ☐ 8 LOOSE SAND OR GRAVEL

ROAD CHARACTER

1 2

- ☐ ☐ 1 UNDIVIDED - ONE-WAY
- ☐ ☐ 2 UNDIVIDED - TWO-WAY
- ☐ ☐ 3 DIVIDED WITH RESTRAINING BARRIER
- ☐ ☐ 4 DIVIDED
- ☐ ☐ 5 RAMP
- ☐ ☐ 6 COLLECTOR LANE
- ☐ ☐ 7 EXPRESS LANE
- ☐ ☐ 8 TRANSFER LANE

☐ ☐ NUMBER OF LANES
☐ ☐ MAXIMUM SPEED
☐ ☐ POSTED ADVISORY SPEED

ROAD PAVEMENT MARKINGS

1 2

- ☐ ☐ 1 GOOD
- ☐ ☐ 2 FADED
- ☐ ☐ 3 NOT VISIBLE
- ☐ ☐ 4 OBSCURED
- ☐ ☐ 5 NO MARKINGS

ROAD CONDITION

1 2

- ☐ ☐ 1 GOOD
- ☐ ☐ 2 UNDER REPAIR
- ☐ ☐ 3 UNDER CONSTRUCTION
- ☐ ☐ 4 OTHER (SPECIFY)

ROAD ALIGNMENT

1 2

- ☐ ☐ 1 STRAIGHT ON LEVEL
- ☐ ☐ 2 STRAIGHT ON HILL
- ☐ ☐ 3 CURVE ON LEVEL
- ☐ ☐ 4 CURVE ON HILL

ROAD TYPE

1 2

- ☐ ☐ 1 ASPHALT
- ☐ ☐ 2 GRAVEL OR CRUSHED STONE
- ☐ ☐ 3 CONCRETE
- ☐ ☐ 4 EARTH
- ☐ ☐ 5 OTHER (SPECIFY)

ACCIDENT INVOLVES* MOVEABLE OBJECTS

VEHICLE 1 2

- ☐ ☐ 1 OTHER MOTOR VEHICLE/S
- ☐ ☐ 2 PEDESTRIAN
- ☐ ☐ 3 CYCLIST
- ☐ ☐ 4 RAILWAY TRAIN
- ☐ ☐ 5 STREET CAR
- ☐ ☐ 6 FARM TRACTOR
- ☐ ☐ 7 ANIMAL
- ☐ ☐ 8 OTHER (SPECIFY)

FIXED OBJECTS

L OR R | DISTANCE FROM ROADWAY

- ☐ ☐ 20 RESTRAINING BARRIER
- ☐ ☐ 21 POLE (RIGID)
- ☐ ☐ 22 POLE (BREAKAWAY)
- ☐ ☐ 23 TREE
- ☐ ☐ 24 POST (SIGN, PARKING METER)
- ☐ ☐ 25 FENCE
- ☐ ☐ 26 CULVERT
- ☐ ☐ 27 BRIDGE SUPPORT
- ☐ ☐ 28 ROCK FACE
- ☐ ☐ 29 SNOW BANK OR DRIFT
- ☐ ☐ 30 DITCH
- ☐ ☐ 31 CURB
- ☐ ☐ 32 CRASH CUSHION
- ☐ ☐ 33 BUILDING OR WALL
- ☐ ☐ 34 OTHER (SPECIFY)

VEHICLE CONDITION

1 2

- ☐ ☐ 1 NO APPARENT DEFECT
- ☐ ☐ 2 SERVICE BRAKES DEFECTIVE
- ☐ ☐ 3 STEERING DEFECTIVE
- ☐ ☐ 4 TIRE PUNCTURE OR BLOWOUT
- ☐ ☐ 5 TIRE TREAD INSUFFICIENT
- ☐ ☐ 6 HEADLAMPS DEFECTIVE
- ☐ ☐ 7 OTHER LAMPS OR REFLECTORS DEFECTIVE
- ☐ ☐ 8 ENGINE CONTROL DEFECTIVE
- ☐ ☐ 9 WHEELS OR SUSPENSION DEFECTIVE
- ☐ ☐ 10 VISION OBSCURED
- ☐ ☐ 11 TRAILER HITCH DEFECTIVE (SPECIFY)
- ☐ ☐ 12 NOT KNOWN
- ☐ ☐ 13 OTHER (SPECIFY)

VEHICLE MANOEUVER

1 2

- ☐ ☐ 1 GOING AHEAD
- ☐ ☐ 2 SLOWING OR STOPPING
- ☐ ☐ 3 OVERTAKING
- ☐ ☐ 4 TURNING LEFT
- ☐ ☐ 5 TURNING RIGHT
- ☐ ☐ 6 MAKING 'U' TURN
- ☐ ☐ 7 CHANGING LANES
- ☐ ☐ 8 MERGING
- ☐ ☐ 9 REVERSING
- ☐ ☐ 10 STOPPED OR PARKED
- ☐ ☐ 11 PULLING AWAY FROM SHOULDER OR CURB
- ☐ ☐ 12 PULLING ONTO SHOULDER OR INTO CURB
- ☐ ☐ 13 NOT KNOWN OR OTHER (SPECIFY)

DIRECTION OF TRAVEL

VEHICLE 1 2

- ☐ ☐ 1 NORTH
- ☐ ☐ 2 SOUTH
- ☐ ☐ 3 EAST
- ☐ ☐ 4 WEST

INITIAL IMPACT TYPE

- ☐ 1 REAR END
- ☐ 2 ANGLE
- ☐ 3 TURNING MOVEMENT
- ☐ 4 SIDESWIPE
- ☐ 5 APPROACHING
- ☐ 6 SINGLE MOTOR VEHICLE
- ☐ 7 OTHER (SPECIFY)

NON-COLLISION EVENTS

- ☐ ☐ 40 FIRE/EXPLOSION
- ☐ ☐ 41 SUBMERSION
- ☐ ☐ 42 ROLLOVER
- ☐ ☐ 43 OTHER (SPECIFY)

APPARENT DRIVER ACTION

1 2

- ☐ ☐ 1 DRIVING PROPERLY
- ☐ ☐ 2 FOLLOWING TOO CLOSE
- ☐ ☐ 3 SPEED TOO FAST
- ☐ ☐ 4 IMPROPER TURN
- ☐ ☐ 5 DISOBEY TRAFFIC SIGNAL
- ☐ ☐ 6 DISOBEY STOP SIGN
- ☐ ☐ 7 FAIL TO YIELD RIGHT-OF-WAY
- ☐ ☐ 8 IMPROPER PASSING
- ☐ ☐ 9 LOST CONTROL
- ☐ ☐ 10 WRONG WAY ON ONE-WAY ROAD
- ☐ ☐ 11 NOT KNOWN
- ☐ ☐ 12 OTHER (SPECIFY)
- ☐ ☐ 13 DISOBEY OTHER CONTROLS (SPECIFY)

DRIVER CONDITION

1 2

- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐
- ☐ ☐

PEDESTRIAN CONDITION

(INVOLVED PERSON NO.) ☐ ☐

- ☐ ☐ 1 NORMAL
- ☐ ☐ 2 HAD BEEN DRINKING
- ☐ ☐ 3 ABILITY IMPAIRED ALCOHOL
- ☐ ☐ 4 ABILITY IMPAIRED DRUGS (SPECIFY TYPE)
- ☐ ☐ 5 FATIGUE
- ☐ ☐ 6 MEDICAL OR PHYSICAL DEFECT (SPECIFY)
- ☐ ☐ 7 NOT KNOWN
- ☐ ☐ 8 OTHER(SPECIFY)

PEDESTRIAN ACTION

(INVOLVED PERSON NO.) ☐ ☐

- ☐ ☐ 1 CROSSING INTERSECTION WITH RIGHT-OF-WAY
- ☐ ☐ 2 CROSSING INTERSECTION WITHOUT RIGHT-OF-WAY
- ☐ ☐ 3 CROSSING INTERSECTION NO TRAFFIC CONTROL
- ☐ ☐ 4 CROSSING PED. CROSSOVER
- ☐ ☐ 5 WALKING ON ROADWAY WITH TRAFFIC
- ☐ ☐ 6 WALKING ON ROADWAY AGAINST TRAFFIC
- ☐ ☐ 7 ON SIDEWALK OR SHOULDER
- ☐ ☐ 8 PLAYING OR WORKING ON HIGHWAY
- ☐ ☐ 9 COMING FROM BEHIND PARKED VEHICLE OR OBJECT
- ☐ ☐ 10 RUNNING INTO ROADWAY
- ☐ ☐ 11 CROSSING THROUGH TRAFFIC
- ☐ ☐ 12 OTHER (SPECIFY)

HIT AND RUN

DRIVER 1 2

- ☐ ☐ 1 APPREHENDED
- ☐ ☐ 2 NOT APPREHENDED
- ☐ NO FURTHER ACTION OR ASSIGNED TO

BREATH TEST

DRIVER

1	2	
☐	☐	1 LOWEST READING (MILLIGRAMS)
☐	☐	2 REFUSED TEST
☐	☐	3 OTHER BLOOD - ALCOHOL TEST

INVOLVED PERSON NO.	INJURED TAKEN TO BY:	RELATIVES NOTIFIED BY:	AMBULANCE CALL NO.	IF SCHOOL AGE CHILD INVOLVED INDICATE SCHOOL NAME

SIGNATURE OF INVESTIGATING OFFICER

VEHICLE TAKEN TO-BY:

1 ☐ HOLD

2 ☐ HOLD

DATE OF REPORT

PERSON CHARGED SECTION & ACT S.C.T. NO.

SIGNATURE OF SUPERVISOR

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