CHAPTER 2: TRAFFIC SIGNAL WARRANTS

2.1 INTRODUCTION

1 Traffic signals are one of the most common and widely accepted forms of traffic control and affect the daily lives of virtually all road users. Traffic signals can be very effective in improving traffic flow and facilitating access. However, traffic signals can also cause significant disbenefit and possible danger to road users when installed inappropriately.

2 There is unfortunately at times a tendency to use traffic signals indiscriminately in an attempt to solve problems where traffic signals are not appropriate. Traffic signals are often seen as the solution to almost all traffic problems, and pressures are often applied for the installation of unwarranted signals. The reasons cited are mostly subjective and emotional and are based on wrong perceptions of the function and abilities of traffic signals.

3 Contrary to popular belief, traffic signals do not always increase safety or reduce delay. In fact, the installation of traffic signals can result in the opposite, namely an increase in delay and a deterioration in safety. Although traffic signals would generally be of benefit to side-road traffic, this could be at a disproportional disbenefit to the main road traffic that previously had unimpeded right of way. It is only at relatively high volumes of side-road traffic where an overall improvement will be realised.

4 The warrants given in this chapter have the objective of avoiding the inefficiencies that can result from unnecessary and improper use of traffic signals. **The installation of traffic signals for the control of junctions and pedestrian or pedal cyclist crossings is warranted when:**

(a) **the traffic signals can meet all the *minimum requirements* described in this manual; AND**

(b) **no viable and feasible *alternative solution* is available which, when implemented, would obviate the need for traffic signals; AND**

(c) **the traffic signals meet the *queue length warrants* as described in this chapter.**

5 **There is no justification for keeping a traffic signal that does not meet ALL the above requirements. The removal of traffic signals at junctions and pedestrian or pedal cyclist crossings is warranted when any one of the above requirements is not met.**

6 A road authority may use the warrants to justify the installation and removal of signals. However, the fact that a signal is or is not warranted does not oblige the road authority to install or remove the traffic signal.

7 Procedures for the installation and removal of traffic signals are described in Chapters 26 and 27 of this manual. The study to establish whether such installation or removal of traffic signals is warranted, forms an important part of these procedures.

2.2 MINIMUM REQUIREMENTS

1 Traffic signals should only be installed when the other minimum requirements described in other chapters of this manual can be met, even if an engineering analysis indicates that signalisation is the optimum method of control and that traffic signals would meet the queue length warrants given in this chapter.

2 There are a large number of such minimum requirements, not all of which are listed below. The most important of these are the following:

(a) Speed limit - the speed limit on any approach to a signalised junction or pedestrian or pedal cyclist crossing shall NOT exceed 80 km/h.

(b) Visibility requirements - traffic signal faces should be clearly visible and recognisable on an approach to a traffic signal.

2.3 ALTERNATIVES TO TRAFFIC SIGNALS

1 The fact that the installation of traffic signals may be warranted in terms of the queue length warrants described in this chapter, does not mean that signalisation is the best or optimum solution to a specific problem. Alternative solutions that are viable and feasible and which, when implemented, would result in a situation in which the installation of traffic signals are no longer warranted, may obviate the need for traffic signals. Such alternatives should be thoroughly explored so that the best solution to the problem is found and applied.

2 Alternatives to traffic signalisation may include, but are not limited to, the following:

(a) Re-designing the geometry of an existing priority control junction to maximise traffic throughput and provide better safety. For instance, the provision of a separate right-turn lane on the stop or yield controlled approach is a particularly effective method of increasing the capacity of such a junction.

(b) The provision of a traffic circle or mini-circle would not only increase the capacity of the junction, but will also significantly improve traffic safety.

(c) Grade separation, if warranted by high volumes of traffic.

(d) Introduction of road closures, bans on turning movements, provision of one-way systems and other traffic management measures.

3 **The redistribution of traffic on the road network by means of traffic calming, road and street closures and one-way systems is a particularly effective and powerful way of reducing the number of traffic signals required in a network. It may be possible to channel traffic to a smaller number of junctions, or alternatively to junctions that are more suitable for signalisation.** Against this, the dangers of undesirable traffic intrusion or rat running in residential areas should always be recognised and avoided.

2.4 TRAFFIC SIGNAL WARRANTS

2.4.1 Introduction

1 Traffic signal warrants are used to indicate levels of activity above which signalisation is justified. Such warrants are used instead of economic analysis methods due to various reasons. Not only are traffic signal warrants easier to apply, but economic analysis also has a problem that it would often indicate that a signal is unjustified, even though there may be chronic congestion during periods with heavy traffic volumes.

2 A problem with traffic signals is that they are often only justified during periods with heavy traffic flow, while serious disbenefits can be incurred when signals are used during off-peak periods. In an economic analysis, the benefit achieved during peak periods can often not outweigh the disbenefit of operating traffic signals for the rest of the time.

3 One of the main advantages of traffic signals that is not normally taken into account in the economic analysis, is that signals distribute priority amongst more than one stream of vehicles, and that one stream of vehicles is not experiencing all the benefit of free flow. At a stop or yield controlled junction, the traffic on the stop or yield controlled approaches has no priority, while main road traffic can move freely through the junction. A traffic signal would result in a better distribution of benefits, although it could result in an overall disbenefit.

4 The levels of traffic activity above which signalisation is warranted have been established on the basis of experience over many years. In South Africa, as well as overseas, it has been found that when these levels are exceeded, delays become excessive and unacceptable to users, often resulting in an increase in traffic accidents.

5 Queue length is used in this manual as the norm for establishing whether the installation (or removal) of traffic signals is warranted.

2.4.2 Queue length warrants

1 **The INSTALLATION of a traffic signal is deemed warranted at a junction or pedestrian or pedal cyclist crossing when ANY one of the following three queue length warrants are met.**

(a) **WARRANT 1: The average length of ANY individual queue equals or exceeds four (4) over any one hour of a normal day.**

(b) **WARRANT 2: The SUM of the average lengths of all queues equals or exceeds six (6) over any one hour of a normal day.**

(c) **WARRANT 3: The SUM of the average lengths of all queues equals or exceeds four (4) over each of any eight hours of a normal day (the hours do not have to be consecutive, but they may not overlap).**

2 **The REMOVAL of a traffic signal at a junction or pedestrian or pedal cyclist crossing is warranted when NONE of the three queue length warrants given above can be met.** This warrant assumes that the existing traffic signal is efficiently timed and appropriate signal phases are used. Inefficient signal timings and inappropriate signal phases may result in excessive queues.

3 A pointsman or scholar patrol can be considered when a traffic signal is warranted for less than one full hour of the day.

4 In the event of a number of traffic signals being warranted, priority should be given to those locations with the longest queues.

5 The traffic signal warrants apply whether or not the signal will be vehicle-actuated or traffic responsive. While these modes of control are preferable at isolated or remotely located junctions, the application of such modes of control does not do away with the need for the traffic signal to be warranted.

6 The following notes must be read in conjunction with the above warrants:

(a) A queue may consist either of vehicles, pedestrians or cyclists stopped or waiting for service at the junction or crossing.

(b) An individual queue of vehicles is the queue waiting in a single lane. On multi-lane approaches, each lane of vehicles would be counted as a separate queue.

(c) An individual queue of pedestrians or pedal cyclists is the total number of pedestrians or pedal cyclists waiting to cross from one side to the other side of the junction or crossing. The pedestrians or pedal cyclists crossing in the opposite direction are counted as a separate individual queue.

(d) An hour must be measured over four consecutive 15-minute intervals, but the four intervals can be selected from any time of the day (normally the peak hour). The queue must be measured over the full hour.

(e) For the eight-hour warrant, the hours can be selected from any eight hours of four consecutive 15-minute intervals. The eight hours do not have to be consecutive, but they may not overlap.

2.4.3 Motivation for the queue length warrant

1 Traffic signal warrants have previously been simplistic, generalised statements giving thresholds for traffic volumes for typical ranges of traffic conditions at typical junctions and crossings. *Queue length* is introduced in this manual as a replacement for traffic volumes as the norm for warranting traffic signals.

2 Queue length has an advantage over traffic volume in that it is directly proportional to the **total** delay experienced at a junction or crossing. Another advantage of queue length is that it provides an indication of the potential accident hazard of such a junction or crossing. As queues build and delay increases, drivers are more likely to take chances, increasing the risk of accidents.

3 A further advantage of queue length is that it automatically compensates for the large variety of traffic, geometric and environmental factors that affect traffic operations at a junction or crossing. It is thus possible to establish only one queue length norm applicable to all conditions. This is in contrast with traffic volumes where different conditions require different norms. In many instances, traffic volume warrants are restricted to a specific set of conditions, while there is NO such restriction on queue length.

4 Additional advantages of queue length as a traffic signal warrant include the following:

(a) It takes into account delay and gap acceptance characteristics.

(b) It compensates automatically for the easier left turn movement at a priority controlled junction. Traffic volume warrants are established for one particular distribution of turning movements, and do not apply outside these parameters.

(c) It takes into account the number of approaches, gradients, sight distance, nearby driveways, pedestrians, and all other geometric conditions, possible distractions and difficulties.

(d) It takes into account the effect of heavy vehicles, buses and bus stops, loading and parking manoeuvres.

(e) By measuring vehicle, pedestrian and pedal cyclist queues together, the different characteristics of these travel modes can be combined.

(f) By including pedestrian and pedal cyclist queues, the speed and gap acceptance characteristics of these users are compensated for.

(g) When a junction is seen or perceived to be dangerous, drivers will be cautious and not proceed until satisfied that the way is clear. This will result in queues building faster than normal, even though traffic volumes may be low.

(h) Account is taken of the fact that it is generally easier to cross a single lane road than a multi-lane road carrying the same volume of traffic.

5 A further important advantage of the queue length warrant is that it is possible to quickly identify candidate locations that may warrant either the installation of new traffic signals or the removal of existing signals. A casual observer can readily observe queue lengths over a short period of time. Detailed warrant studies can then be undertaken once such candidate locations have been identified.

2.4.4 Measuring queue lengths

1 The average queue length required for the warrant analysis can be established in one of two ways:

(a) Field observations.

(b) Traffic modelling.

2 Field observations are always more accurate than traffic modelling, particularly at priority controlled junctions or pedestrian or pedal cyclist crossings where traffic operations can be affected by a large number of factors. Field observations are therefore generally preferable to traffic modelling for establishing queue lengths.

3 When the possible removal of traffic signals is investigated, at least eight hours of observations would be required to establish whether such removal is warranted.

2.4.5 Field observations of queue lengths

1 Queue lengths at junction or crossing are observed by counting the number of vehicles, pedestrians or pedal cyclists waiting to be served at a junction or crossing. Each **individual** queue of traffic should be counted separately. The definition of an individual queue is given as part of the warrants.

2 Queue lengths are counted at regular time intervals of typically 15, 30 or 60 seconds. The appropriate time interval depends on whether traffic patterns on the main road (road without stop or yield control) are random or platooned due to the presence of nearby traffic signals:

(a) When traffic on the main road is heavily platooned due to the presence of nearby traffic signals, a time interval of 15 seconds would typically be used. However, should queues become so long that it is difficult to count the queue length, a longer time interval of about 30 seconds may be used.

(b) Where traffic on the main road is slightly platooned due to the presence of traffic signals on the main road, a time interval of 30 seconds may typically be used.

(c) When traffic on the main road is random with no discernible platoons formed due to traffic signals on the main road, a time interval of 60 seconds may typically be used.

3 **It is important to note that queue length should be counted as quickly as possible at the end of a time interval, and not during the time interval. The queue length is required at a point in time rather than over a period of time, as shown in Figure 2.1.**

4 **The average queue length is calculated by adding together the observed queue lengths during a time interval (including zero queue lengths) and dividing the sum by the number of observations. An example of such calculations is shown in Figure 2.1.**

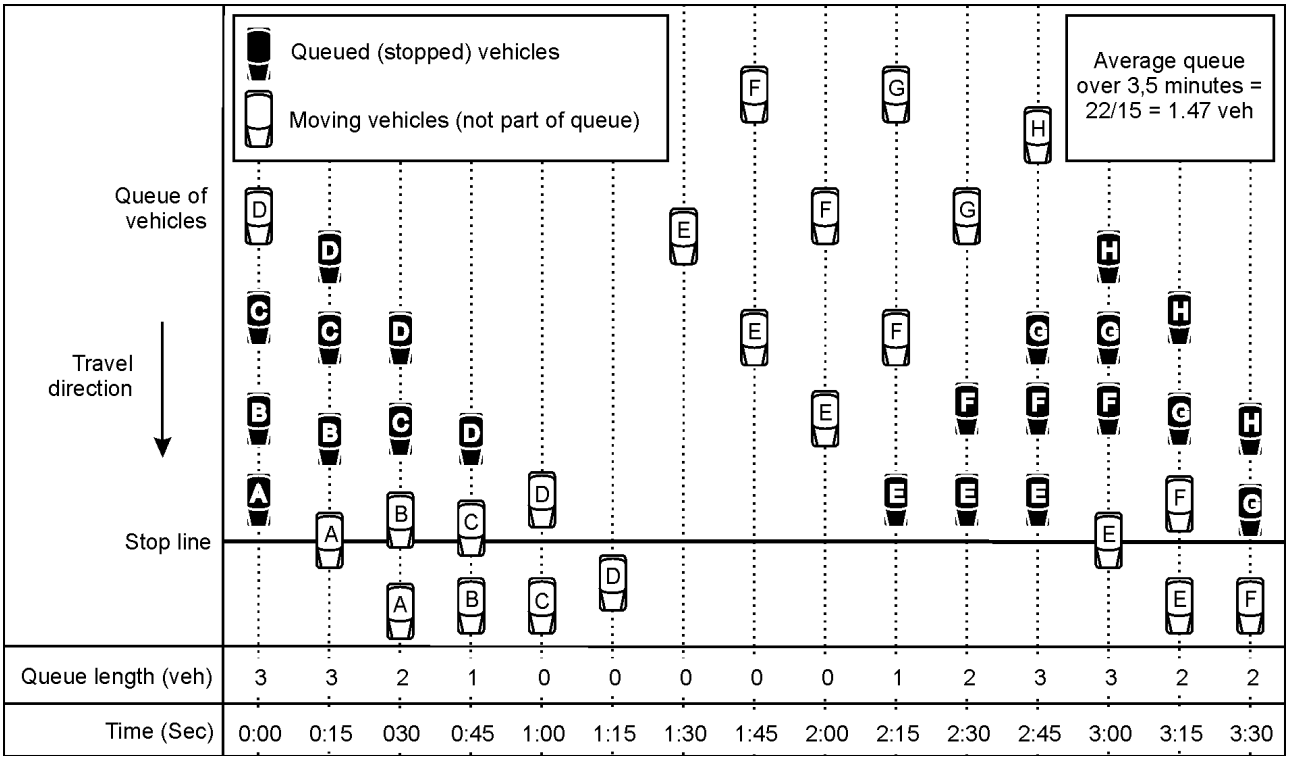

Figure 2.1: Queue length observations

5 The field observations can be significantly simplified by providing observers with an electronic watch and bleeper. The watch should show time to the nearest second and should sound bleeps every 15 seconds. One bleep is sounded at 0 seconds, two at 15 seconds, three at 30 seconds and four at 45 seconds.

6 Observers should be carefully trained. It is recommended that a video recording of a queue at a junction or crossing be used during the training. Each observer should be tested carefully to determine whether he or she understands the procedure of counting queue lengths exactly. Some observers who are used to counting traffic volumes, find it difficult to adjust to queue length counts since queue lengths are counted at the end of an interval, while traffic volumes are counted during the interval.

2.4.6 Traffic modelling of queue lengths

1 It is not always possible to undertake field observations of queue lengths, and traffic modelling will then have to be resorted to. Field observations of queue lengths, for instance, are not possible at new junctions that have not yet been constructed. This would typically occur when a new development is planned. During the Traffic Impact Study required to establish the impact of such development, the need for additional traffic signals at new accesses or junctions must be established based on traffic modelling and using the traffic signal warrants.

2 Traffic modelling will also be required where changes to the road network, or the installation of a new traffic signal, would result in a redistribution of traffic in an area. A newly signalised road junction may attract drivers from nearby priority controlled junctions who may find that by diverting to the signalised junction, they experience less delay. These scenarios would entail a more rigorous traffic planning analysis with the purpose of estimating the likely traffic volumes at the junction or crossing being evaluated.

3 A variety of computer traffic models are available, although some manual methods are also used. The estimation of queue lengths by means of a traffic model is a complex exercise and should be undertaken with circumspect. All traffic models are based on some idealised representation of reality, which may, or may not, be representative of actual traffic operations. Some models are more accurate than others, but all models have limitations. The results of such models should therefore be used with caution.

4 Some models can calculate average queue lengths directly. Some models calculate 90^{th} or 95^{th} percentile queue lengths. These should not be used, **as it is the average queue length that is required**. Where queue lengths are only provided per approach and not by lane, such queue lengths should be divided by the number of lanes on the approach to establish the average queue length per lane.

5 Some models only provide average delay as output and not queue length. The average queue length can then be calculated by means of the following formula:

$$N_i = \frac{D_i \cdot Q_i}{3600}$$

in which:

N_I = Average queue length in lane i.
D_i = Average delay of vehicles in lane i in units of seconds/vehicle.
Q_i = Arrival flow rate in lane i in units of vehicles/hour/lane.

2.4.7 Normal days

1 An important consideration in establishing queue lengths, is that such queues should be established for a normal day rather than for an exceptional day.

2 A normal day is one on which traffic flow is relatively stable, unaffected by events such as traffic accidents, road closure, construction, inclement weather, special sporting events and during school terms. Exceptional days include public and school holidays, as well as days on which traffic patterns are abnormal due to the conditions as mentioned above. More information on normal and exceptional days is given in Chapter 29 of this manual.

3 Traffic counts and queue length observations should be discontinued or discarded when an exceptional event has occurred that may have affected the observations.