CHAPTER 9: AREA TRAFFIC CONTROL

9.1 INTRODUCTION

1 The co-ordination of traffic signal controlled junctions is highly beneficial to the flow of traffic through a network of traffic signals or along an arterial road. The major objective in co-ordinating traffic signals is to permit continuous flow of traffic through such a network. A co-ordinated system will significantly reduce vehicular delays and stops with commensurate savings in number of accidents, fuel consumption, levels of air pollution, etc.

2 Signals at different junctions can be co-ordinated by using a common signal cycle length and a set of signal offsets that determine relative time relationships between adjacent signals. The use of a common cycle length synchronises the signals and assures that the relative timings of the signals will be repeated regularly.

3 Traffic signals can be particularly effective when co-ordinated in a network, compared to isolated control. In a network, traffic flow patterns are typically relative stable, strongly platooned and cyclic. Under such conditions, it is possible to achieve a relatively high level of efficiency. On the other hand, these same conditions can have exactly the opposite impact if signals are not properly co-ordinated. Operations can become extremely inefficient in an unco-ordinated traffic signal system.

4 Modern area traffic control systems utilise a central computer for storing and implementing traffic signal plans. This was made possible by the rapid development in computer technology and telecommunications. These systems have grown in sophistication and are commonplace in most major cities throughout the world.

5 There are numerous methods of implementing traffic signal co-ordination, ranging from the very simplistic through to real time traffic responsive control. All of these methodologies fall under the collective term of Area Traffic Control (ATC). The following systems are discussed in this chapter:

(a) Master signal control
(b) Fixed time area traffic control
(c) Adaptive area traffic control
(d) Traffic responsive area traffic control

9.2 MASTER SIGNAL CONTROL

1 A relatively simple method of co-ordinating traffic signals in a small signal network or on an arterial is by utilising a local master controller. This master controller is used to synchronise local controllers in the system.

2 The implementation of local master-slave co-ordination is shown in Figure 9.1 and requires the following equipment:

(a) A specifically designated master controller (this may be separate or it may double as a standard signal controller).
(b) Slave controllers at each road junction and signalised pedestrian crossing.
(c) A pilot cable connecting each of the slave controllers to the master.

3 The pilot cable is utilised for the transmission of information to affect timing plan changes, and to maintain synchronisation and co-ordination of the controllers.

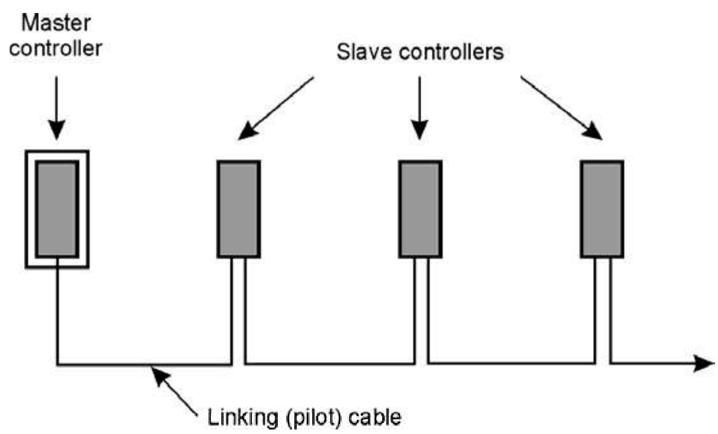

Figure 9.1: Schematic for linking co-ordinated signals

9.3 FIXED TIME AREA TRAFFIC CONTROL

1 The simplest form of area traffic signal control is by means of a fixed time system. Plan preparation is undertaken off-line and plan selection can occur by time of day or using automatic plan selection methods.

2 Automatic plan selection provides an area control system with the ability to introduce fixed time plans in response to detector inputs. A plan may be introduced on the basis of inputs such as the following:

(a) A count detector exceeding a threshold (either the absolute value or the rate of change in the traffic count).

(b) A queue detector detecting a long queue.

(c) An occupancy detector exceeding its threshold.

3 Plans can be selected by means of Boolean logical expressions or a method whereby each plan is allocated a priority based on the detector inputs. Transitional plans can be provided to allow the controller to step up or down towards the required signal plan.

4 Fixed time area control has the disadvantage that signal plans must be prepared manually. These plans must also be updated regularly to reflect changing traffic conditions, which require costly data collection and analysis. Automatic plan selection improves the flexibility of the system, but does not reduce the need for the manual and regular updating of plans.

9.4 ADAPTIVE AREA TRAFFIC CONTROL

1 Adaptive and responsive control systems have been developed with the objective of overcoming shortcomings of fixed time control systems. Such systems can react automatically to changes in traffic conditions on the road network.

2 Adaptive traffic control utilises simpler control strategies than the traffic responsive systems described in the next section. Although simpler, adaptive control can provide relative efficient traffic signal control.

3 The adaptive strategy described below is the one used in the SCATS system (Sydney Co-ordinated Adaptive Traffic System). This system was developed by the Road and Traffic Authority of New South Wales in Australia.

4 The system utilises stop line detectors for the collection of traffic flow data. A detector loop is placed in each lane approaching a junction as shown in Figure 9.2. Some lanes, however, can be left without any detectors.

5 The stop line detectors are used to estimate the *degree of saturation* for each lane approaching a junction. This degree of saturation is estimated as used green divided by total available green. Used green is taken as the number of vehicles crossing the detector multiplied by the average saturation flow headway. These degrees of saturation are used to optimise traffic signal timings as follows:

(a) Cycle lengths are established based on the degree of saturation. A target cycle length is selected, and the actual cycle length changed in steps of a few seconds in the direction of the target cycle length. A large step size is used when there is a steep change in traffic demand.

(b) Green splits are established that will result in equal degrees of saturation on critical lanes.

(c) Signal offsets are undertaken on a selection basis. A number of offsets can be provided for each link, and the system selects the offset most suitable to the level of traffic flow on the link. The offsets are calculated off-line (as for fixed time plans).

(d) Signal phases can be defined, and any phase for which no traffic demand has been registered, may be skipped.

6 The SCATS system has been extensively developed and tested, and a variety of refinements have been developed to ensure reliable operation. The system has demonstrated its value compared to fixed time control and is particularly effective when responding to unpredictable traffic patterns. Being traffic adaptive, the need for regular updating of signal settings is obviated.

9.5 TRAFFIC RESPONSIVE CONTROL

1 Traffic responsive control systems utilise a relatively complex traffic model for the on-line estimation of a performance index and establishment of optimum traffic signal settings. The system is therefore self-optimising, and can respond to changes in traffic patterns and flows.

2 The control strategy described below is the one used in the SCOOT system (Split, Cycle and Offset Optimisation Technique). This system was jointly developed by the Transportation Research Laboratory and three prominent traffic signal companies in the United Kingdom.

3 The system utilises detectors that are located some distance upstream of the stop line as shown in Figure 9.3. Traffic flows measured at these detectors are used to predict a traffic arrival profile at the downstream stop line using platoon dispersion models. An example of such a projected stop line demand profile is shown in Figure 9.4.

4 Predetermined saturation flows are used to estimate queue lengths from which delays and number of stops can be calculated. A performance index is determined as the weighted sum of delay and number of stops. This index is recalculated every few seconds from the latest traffic flow measurements, and is used to establish optimum cycle length, green splits and signal offsets.

5 The upstream detectors also have the added advantage that queues extending back to the detectors can be detected, which allow appropriate actions to be taken to avoid blocking of junctions.

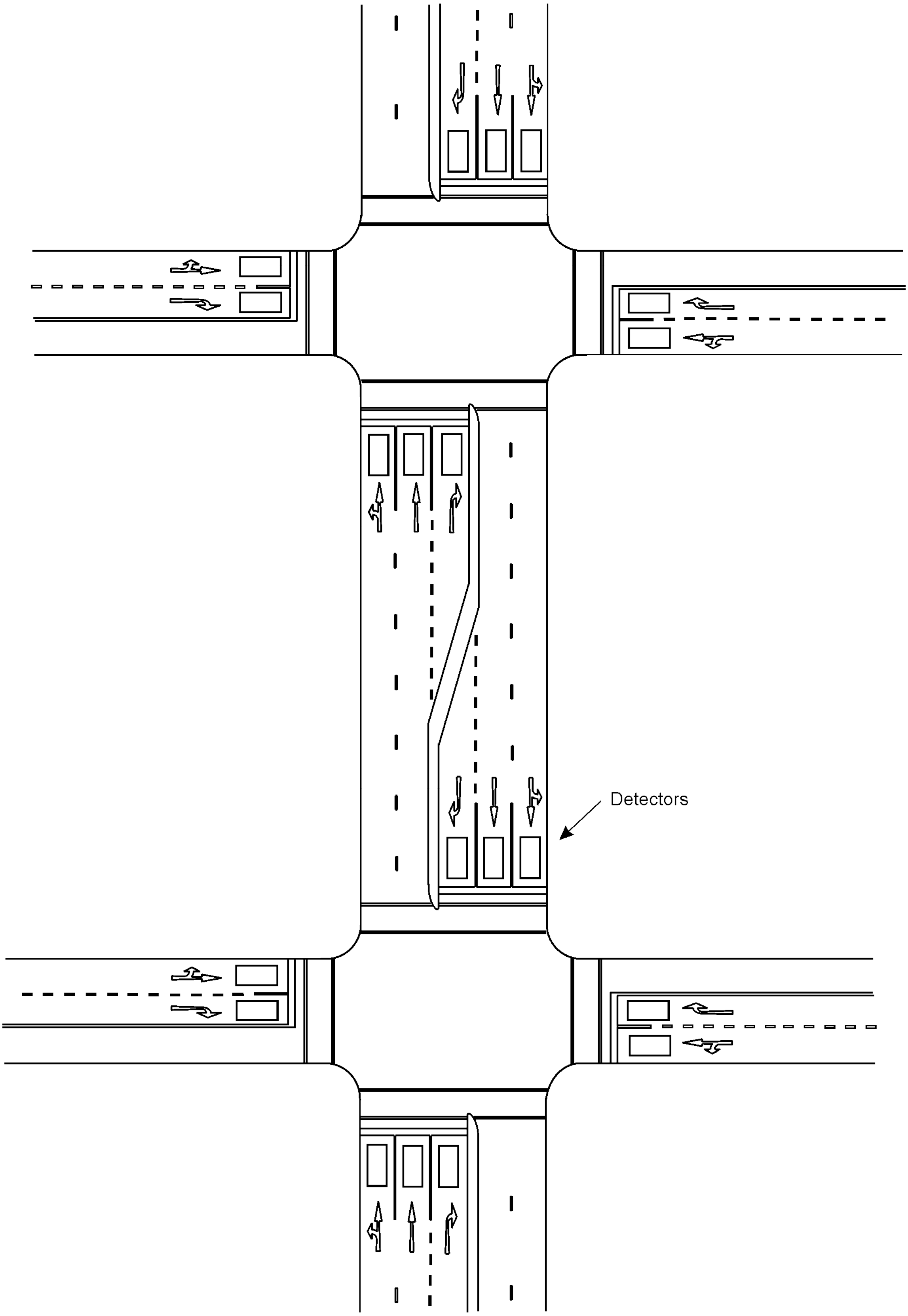

Figure 9.2: Adaptive traffic control vehicle detector layout

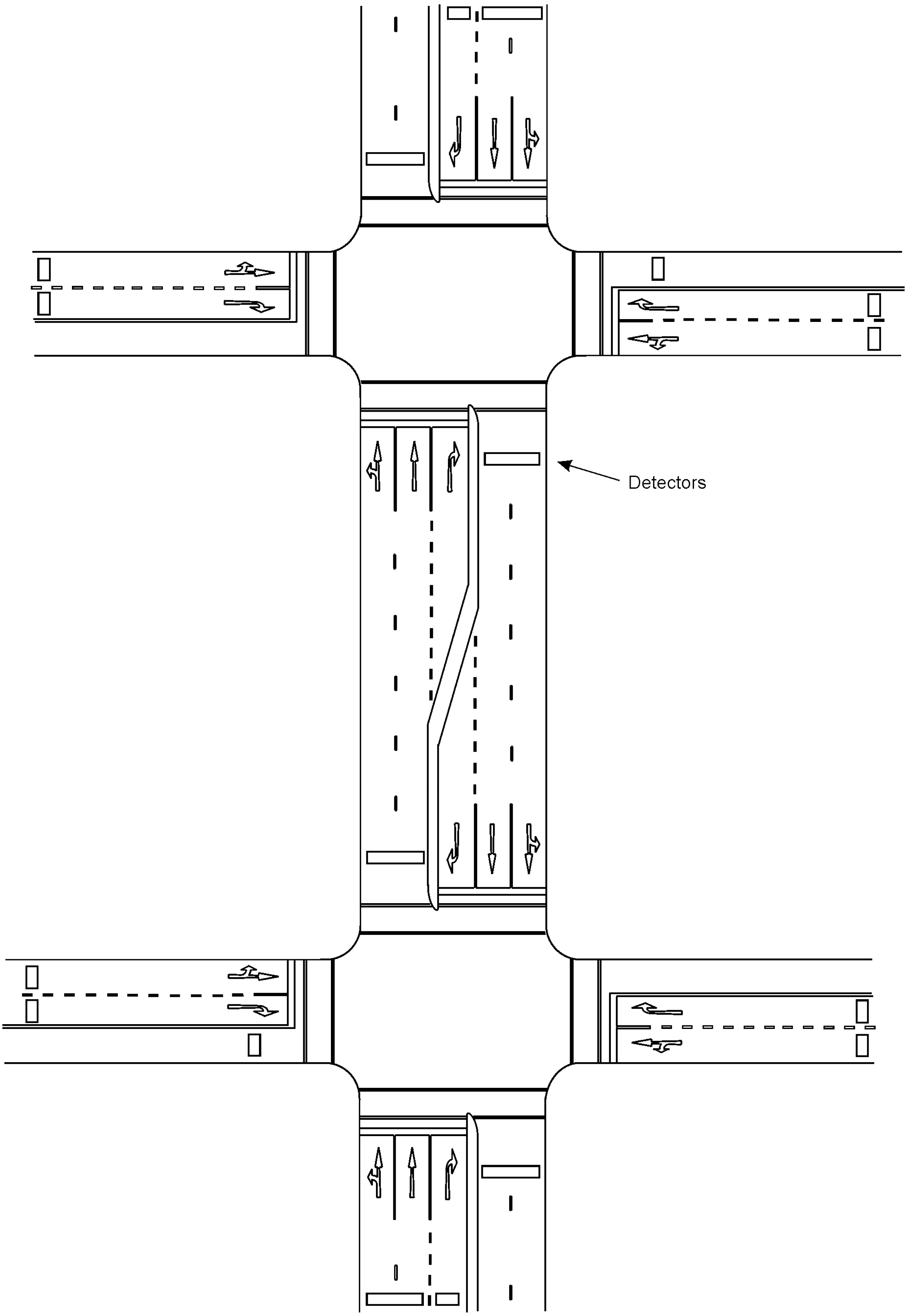

Figure 9.3: Traffic responsive control vehicle detector layout

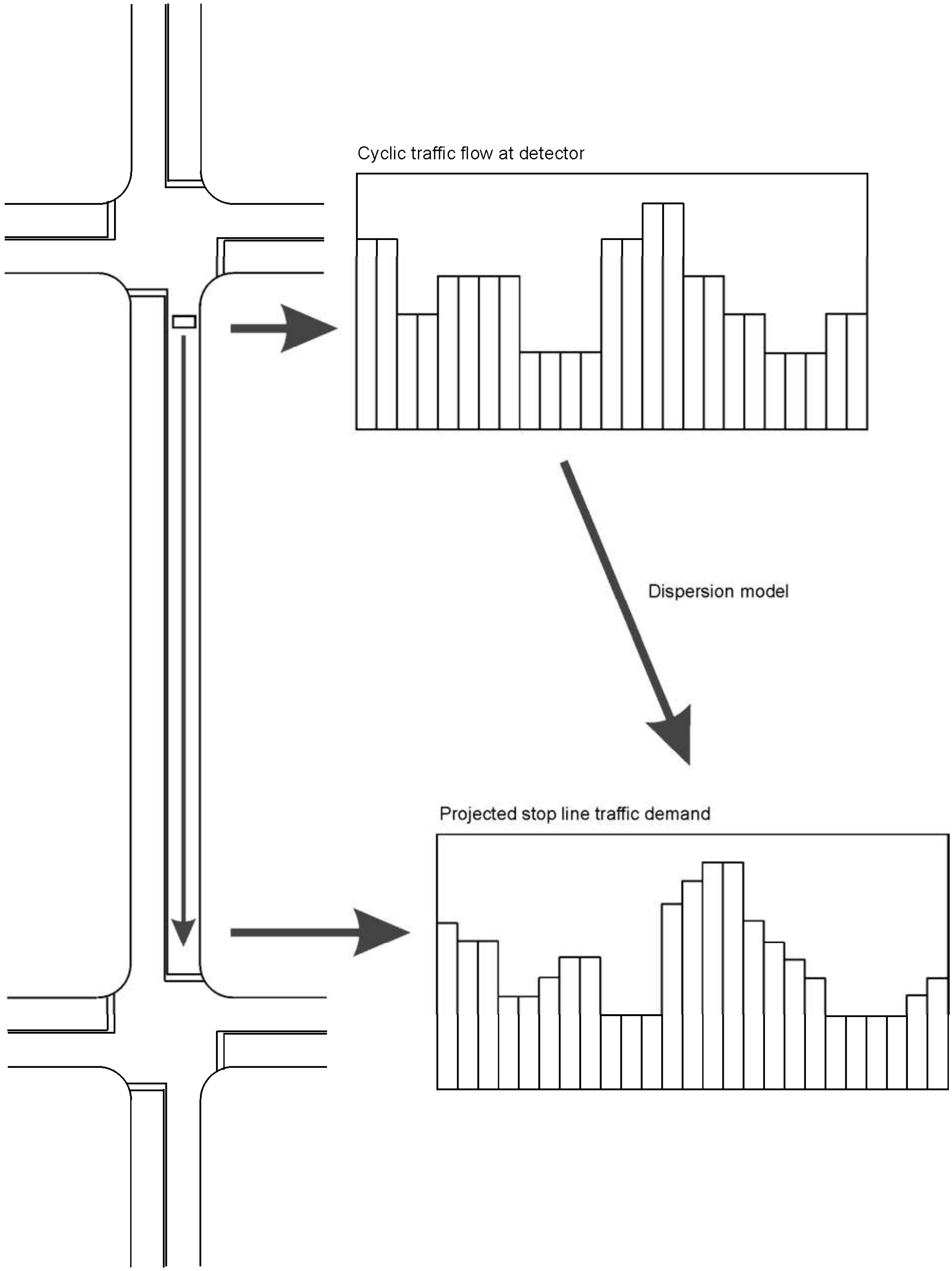

Figure 9.4: Projected traffic demand profile at downstream junction

6 The optimisation process is continued throughout the day. During low flow conditions, a shorter cycle length is used. The cycle length is increased gradually during periods of high traffic flow. Green splits are also adjusted based on flow patterns.

7 The SCOOT model requires a minimum number of basic parameters that are stored in a database. These parameters include the following:

(a) A network description in the form of nodes, links and detectors that must be coded according to prescribed rules. During this process, detectors are associated with links and links associated with downstream links and signal phases.

(b) The free-flow journey times from upstream detectors to downstream stop lines.

(c) The discharge rate from the stop line in Link Profile Units (LPU's). This is similar to saturation flow and is a critical parameter in the system that is determined during validation.

(d) Timetables which specify which signal plans should be operative and at what time of the day, day of week etc. Provision is usually made for a full year calendar to allow for public and school holidays.

8 On completion of the data preparation, a validation process is undertaken to ensure that the model accurately represents what is happening on the street network. Specific software is available to assist with this process. This should preferably be undertaken using a mobile computer and GSM connection to the instation computer. The importance of this validation process cannot be overemphasised.

9.6 BENEFITS OF ADAPTIVE AND RESPONSIVE SYSTEMS

1 There is a significant learning curve before systems such as SCATS and SCOOT can be used with confidence. Experience has, however, shown that the rewards in using these systems exceed the effort.

2 Field evaluations have shown that both systems can provide significant savings in fuel consumption, journey time and stops over and above conventional fixed time plans. These savings are further purported to increase significantly when compared with fixed time plans that have not been updated for a number of years.

3 Figure 9.5 shows the flexibility of traffic adaptive or responsive control compared to fixed time. There is a limit to the number of fixed time plans that can be developed, with the result that a plan must be utilised over a period of time during which the plan may not necessarily be optimal. In Figure 9.5, a total of six timing plans have been used over a period of 12 hours, and even these are not adequate to cope with the varying traffic demand. A traffic adaptive or responsive control system is able to respond to actual traffic demand in real time.

4 Definitive comparisons between SCOOT and SCATS have not been possible due to the divergent loop placement philosophies. Both systems provide positive benefits compared with fixed time operation and as is the case with many systems, both have their advantages and disadvantages.

5 Most cities in South Africa have opted for the SCOOT system. The need to share knowledge and experience with peers is an important motivation why preference can be given to the SCOOT system. However, when skilled manpower is available, there is no reason why the SCATS system or other systems cannot be considered.

9.7 DATA ACQUISITION BENEFITS

1 An added benefit of a traffic responsive system is the opportunity provided for acquiring traffic data for purposes other than traffic signal control. Due to the communication capabilities of such systems, it is also possible to collect traffic data in real time.

2 The data collected for the purposes of traffic responsive signal control are not perfectly accurate. It is, however, possible to develop adjustment factors based on traffic data collected by other means, such as automatic counting stations. These factors are used to improve the accuracy of the traffic data collected by the traffic responsive system.

3 The traffic data collected as part of the traffic signal control system can be utilised in a variety of applications. These applications are not only limited to those that are of value to the traffic engineer, but can also be of benefit to the public.

4 An important possible application for which such data can be utilised is the determination of congestion levels. The SCOOT system in fact allows for the direct estimation of vehicular delays at individual signals. Such information is available in real time and can form part of a driver information system in which information is provided on quickest available routes to destinations. Various methods of communication can be used for this purpose, such as computer networks or radio broadcasts.

5 The traffic data are useful in many traffic engineering applications outside traffic signal design. Such information can, for instance, be utilised for the production of traffic flow maps in which traffic volumes are indicated by bands of variable width. Such flow maps can be particularly useful in the overall planning of a road and street network.

6 The above data acquisition benefits of traffic responsive systems should be taken into account when a road authority is considering the introduction of such a system.

9.8 BIBLIOGRAPHY

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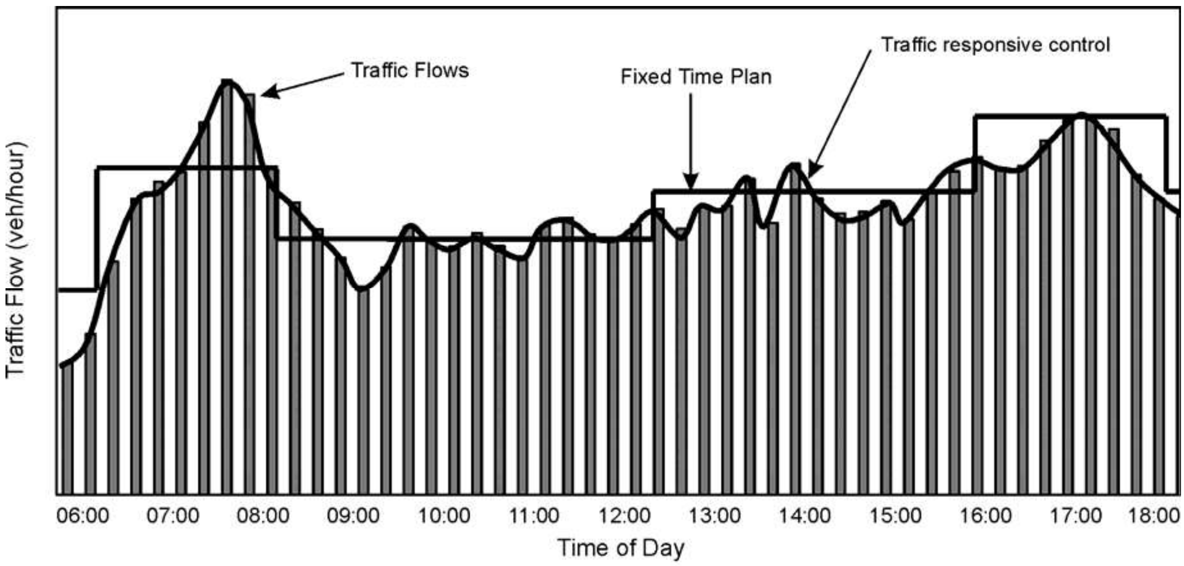

Figure 9.5: Flexibility of traffic responsive control