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Cycling and Urban Traffic Management and Control Systems

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Since the 1950s, cycling has been a declining mode of travel in the United Kingdom. During this same period, sophisticated techniques for managing traffic in the urban environment have been developed. Given these circumstances, the presence of cyclists is often ignored by urban traffic control (UTC) systems, which are dominated by consideration of the flows and journey times of private motorized vehicles. Authorities are enthusiastic about the promotion of cycling as a mode of travel and are looking to see if this can be assisted by use of traffic management systems. The fact that cyclists and potential cyclists vary considerably in their abilities and performance, as well as in their attitudes to timesaving and safety, is highlighted. The context of the problem is set, the specific issue of detection of cycles is examined, the potential for implementation of priority measures in different types of UTC systems is discussed, and the issue is illustrated with some actual installations. Limited European evidence would suggest that only minimum effort is needed to take explicit account of cycling when a UTC system is being implemented. This supports the idea that cyclists can be given a higher degree of consideration within a UTC system without incurring significant additional costs. Only when cycling achieves a near-dominant proportion of the trips within a city and is growing in volume, as is the case in China, is explicit consideration to cyclists given.

Governments see increased mobility as a good thing since it generally extends individuals' choice and allows them to participate in a wider range of leisure activities. Unfortunately this mobility has typically been provided by private motorized transport, which has associated problems, including air pollution, fuel consumption, noise, congestion, and driver stress. Authorities are therefore looking for ways to maintain or enhance individuals' mobility without reliance on private motorized forms of transport. These alternative modes include public transport (tram, bus, coach or train), cycling, and walking.

The United Kingdom (U.K.) government has reaffirmed a set of targets in the National Cycling Strategy (NCS) (*1*). This strategy includes the target of doubling cycling trips by the year 2002 and quadrupling them by 2012, based on 1996 figures. This is, in part, to be achieved by a partnership between public, commercial, and voluntary organizations. The recent White Paper endorses the NCS as part of the package of measures aimed at providing an integrated transport policy that will be "better for everyone" (*2*).

These targets are ambitious but are based on a low baseline of cycle use. Within the United Kingdom, the role of cycling as a mode of transport has diminished. In 1952 there were 23 billion passenger kilometers traveled by cycles, 11 percent of the total. This has fallen to only 4 billion passenger kilometers, 1 percent of the total, in 1997.

It is during the period of decline for cycling that development of sophisticated urban traffic control (UTC) systems has taken place. In common with other industrial nations, the U.K. government has begun to look at how to manage the demand for travel, rather than just the vehicles, in order to meet targets. Targets arise from the implications of the United Kingdom's signing of the accord produced at the 1992 Earth Summit in Rio and, additionally, from the legally binding commitments of the subsequent Kyoto Summit. In addition, the U.K. government has also produced its National Air Quality Strategy to address the problems of localized pollutants (*3*). Given that motorized transport contributes a high proportion of most of the atmospheric pollutants, any move away from such forms of transport is likely to assist in the achievement of the government's air-quality targets. On a local level, the U.K. Road Traffic Reduction Act of 1997 obliges traffic authorities to review levels of motorized traffic and produce proposals for reducing traffic or the rate of growth of traffic. Such proposals are likely to be put forward as part of the new local transport plans that local traffic authorities are now required to produce.

The U.K. government sees more adaptable and integrated urban traffic management and control systems (UTMC) as a tool to help achieve the aims set out above. The specific question then arises as to how urban traffic management can be configured to make cycling more attractive and, specifically, safer and quicker.

PHILOSOPHY OF URBAN TRAFFIC MANAGEMENT AND CONTROL SYSTEMS

In 1996, the U.K. Department of the Environment, Transport, and the Regions established a research program into UTMC systems (*4*). The goals are

- To enable the efficient exchange and use of information by component systems,
- To build in the flexibility to incorporate and develop new strategies,
- To enable efficient strategy selection, and
- To enable migration to take place from existing urban traffic management systems and equipment.

One of the central ideas behind UTMC systems is that they will be open and modular, with the communications between modules rigidly defined. International standards will be used and the approach is one of providing a framework for a system, which may be easily and gradually built up from components (some of which may already exist). This should allow standard components to be supplied by different suppliers and simply "slotted in" so that systems can easily be tailored to local requirements by the removal or addition of modules. The system will be composed of links and of five different types of nodes (Figure 1).

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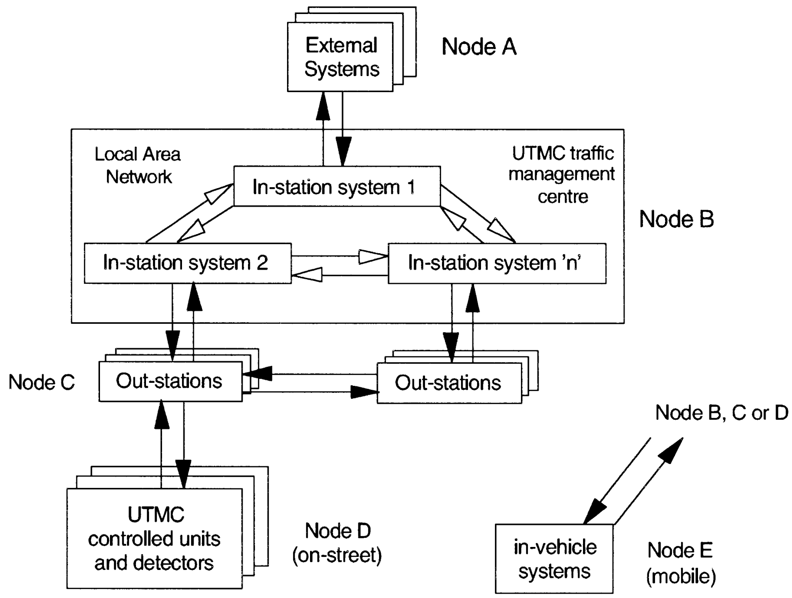

FIGURE 1 Logical reference model for UTMC (*4*).

Type A nodes are external systems with which the UTMC system may wish to communicate. These could be other UTMC systems, police and other authorities' systems, and the like. The Type B node is the UTMC management center, and Type C nodes are the intelligent outstations that will be able to talk to each other. Type D nodes are passive controlled units, which will include the traffic signals themselves and traffic detectors, as well as other units such as variable message signs. Type E nodes are in-vehicle units that could be simple passive devices such as route guidance systems, but could also include more sophisticated devices such as road pricing equipment.

The UTMC specification was developed in order that current and future needs could be accommodated through a research program composed of two elements, a Directed Program and a Responsive Program. In late 1998, a project called Minimum Cycle Time was funded under the Responsive Program. The broad aims of the project were to examine the literature to see how cycling had been incorporated into existing UTC systems and what scope there was to take this consideration further. The full report is available from the UTMC website (*5*).

ATTITUDES TOWARD CYCLING

In a survey of 350 households in Southampton, the views of cycling by potential cyclists were sought (*6*). Some of the respondents' concerns were clearly beyond the control of the authorities (e.g., terrain and weather), but others were physical in nature (e.g., secure parking and cycle routes) and thus were suitable for action by the authority. The remaining views were attitudinal (e.g., cycling was not taken seriously or cycling was thought to be a good form of exercise). Also, in recent years there has been an increase in the "school-run," in which parents drive their children to school rather than allowing them to walk or cycle. Reasons often stated for this are safety concerns both about the amount of traffic on the roads and the fear of attack. The Automobile Association published a report on the attitude of motorists toward cycling as an alternative mode (*7*). The survey included 189 cycling motorists, 121 leisure-only cyclists, and 690 noncycling motorists. Table 1 summarizes reasons given by survey participants for cycling or not cycling.

Safety is clearly an important consideration for cyclists and potential cyclists, but perceptions of safety will vary considerably by type of cyclist and journey purpose. Reports from the Institution of Highways and Transportation (*8*) and the Center for Research and Contract Standardization in Civil and Traffic Engineering (*9*) suggest that the following factors are all important for cyclists:

- Coherence—cycling infrastructure should be coherent;
- Directness—routes should be as direct as possible and follow desired lines;
- Attractiveness—"soft" factors such as lighting, aesthetics, and personal security are also important;
- Safety—designs should minimise danger to cyclists; and
- Comfort—routes should be smooth, convenient, and well maintained.

TABLE 1 Possible Determinants of Cycle Use (*7*)

Reasons for Cycling	Reasons for Not Cycling
Good exercise	Available use of a car or motorcycle
Good for the environment	No bicycle
Fun and sociable	Too dangerous
Can be quicker	Too old
Cost savings	
Easy parking	

EXISTING FACILITIES

This section will draw mainly on the existing facilities for cyclists in the United Kingdom. A general description of recommended cycling facilities is available in reports by the Institution of Highways and Transportation and Edinburgh City Council (*8*, *10*). The existing facilities for cyclists are described in four categories: off-road facilities, on-road facilities, junction facilities, and roundabouts.

Off-Road Facilities

Off-road facilities are typically shared use pedestrian-cyclist pathways, on which one half of the pavement or sidewalk is divided off for two-way use by cyclists, thereby creating what can be perceived to be a safe but slow environment for the cyclist, but a less safe environment for pedestrians. Some authorities, typically those for a planned or historic city or town, have introduced or maintained a coherent network of segregated cycleways. A completely segregated network of cycle routes is not, however, possible, and at some point on a segregated facility, the route must cross a general traffic lane or travel through a traffic junction. In both these cases, the crossing is usually under some form of signal control. Within the United Kingdom, Toucan crossings are commonly used to allow pedestrians and cyclists to cross traffic lanes. The Department of Environment, Transport, and the Regions produces an ongoing series of Traffic Advisory Leaflets that highlight particularly innovative aspects of such implementations (*11*).

On-Road Facilities

The most universal provision for cyclists on the main carriageway is a wide curbside lane, typically 4.5-m rather than 3.6-m wide, that allows cyclists to be safely overtaken. In some instances this extra space may be marked off to form an advisory or mandatory cycle lane. Along a street that is one way for general traffic, a contraflow cycle lane may be implemented. In urban areas it is also common for sections of the curbside lane to be reserved for use by public transport, and cyclists are also able to use this lane. The greatest degree of segregation is at locations where there is a physical barrier between the cyclist and the remaining traffic.

Junctions

At both signalized and priority junctions, cycles can behave as any other vehicle would. Additional care needs to be taken to ensure that a cyclist leaving an arm of the junction at the end of green can reach a safe position before conflicting movements are permitted. An increasingly common feature at signal-controlled junctions is the advanced stop line. Here the stop line for motor vehicles is set back at a distance of 2 m to 3 m, creating a box of space that allows cyclists to move to the head of the traffic queue or maneuver to make an opposed turn. Once again there are a number of Traffic Advisory Leaflets that describe good practice in this area (*11*). The report by Ryley contains a twin study of access arrangements to the advanced stop line and the impact of the signal control regime at the junction (*12*). Of the five test sites, three were operated under a vehicle-actuated scheme, whereas the remaining two were under the control of the adaptive UTC system known as Split Cycle Offset Optimization Technique (SCOOT) (*13*). In all cases, the length of the green stage for cyclists was determined by the vehicle flows on the corresponding links. The report concluded that the form of control had little impact on cyclists and that in all cases cyclists adapted their behavior to ensure that they made the safest possible maneuvers through the junction. This adaptation involved the choice of lane on approach to the junction and the timing of their arrival at the stop line.

In situations in which the cycleway forms a distinct entrance to the junction, either a dedicated signal stage is required within the normal signal cycle to allow cyclists to travel on, or, where cycle demand is low, some form of detection is required. This detection may be passive, using loops buried in the road surface or pole-mounted microwave/ultrasound/passive infrared devices, or active, using a push-button device the cyclist is expected to press.

Roundabouts

Roundabouts are a common feature of the U.K. and European road infrastructure. They can be operated in a priority manner, with priority usually being accorded to the circulating traffic, or they can be partly or fully signalized. Priority roundabouts are a well-known safety concern for cyclists (*14*). Of particular concern are the problems of motorized vehicles' approaching the roundabout at high speed and colliding with cyclists already on the roundabout. Measures that can be adopted to mitigate this impact are signalization of the roundabout or adaptation of the physical design to a more continental approach (*15*, *16*).

DETECTION OF CYCLISTS

Even the simplest requirement of detecting a cycle in a dedicated lane using traditional loop technology can prove to be a challenge. A report by Davis et al., primarily concerned with the monitoring aspects of cycle use, contains a section on monitoring equipment, in which the loop technology that may be suitable for cycle detection is discussed (*17*). Pneumatic loops on the road surface are a cheap solution and can be installed with a minimum of disruption to traffic. They are not, however, very robust to heavy traffic flows. A second and more innovative loop is composed of piezoelectric strips. These strips detect the presence of a vehicle by sensing the pressure exerted by the vehicle and converting this pressure into an electrical signal. They are accurate, with a quoted performance accuracy of 95 percent, and durable, lasting from 3 to 5 years. Of the loop technologies considered here, they are, however, the most expensive. The most durable loops are inductive loops, which are buried in the surface of the road. A detection is triggered by the movement of a body of metal through a magnetic field created by the loops. Here cycles are at a disadvantage since they have a small cross section and, when the effective area of the loop is considered, contain relatively low amounts of metal. With suitable calibration and sensitivity settings for these loops, however, registering the presence of a cycle using induction loops is possible.

Leschinski includes a study of the effectiveness of inductive loop technology at detecting a cycle (*18*). This study measured the effectiveness of the loop with regard to four loop designs, four sensitivity settings, three cycle types, and eight straight-line paths over the loops (Figure 2). Of the four designs tested, the most consistently good in terms of correctly identifying the passage of a cycle was the loop design adopted for the implementation of SCOOT in Bei-

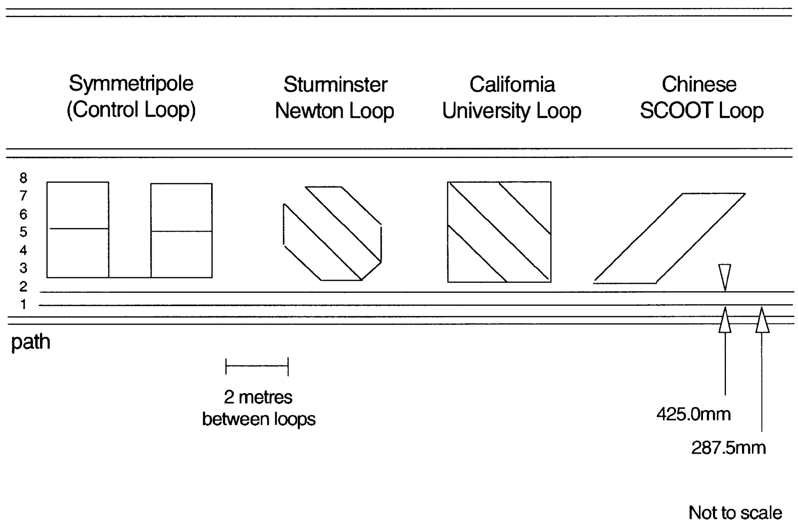

FIGURE 2 Four loop designs and eight paths across loops.

jing (*19*). The loop design was able to record at least 90 percent of detections by all cycle types traveling in the middle 80 percent of the loop at both high- and low-sensitivity settings. The other three loops, two of which had been designed for cycle detection, performed well on the high-sensitivity setting but poorly on the low setting. The detection performance for cars on all four loop types was assumed to be adequate.

As part of a comprehensive upgrade of traffic signal equipment initiated by the Montana Department of Transportation, special attention was given to the effectiveness of new loop designs in the detection of bicycles (*20*). The final design adopted resembles the California University loop design tested in the study by Leschinski (*18*). The interesting feature of this redesign was that the roadway was marked with a line and a symbol that indicated the path over the loop that was most sensitive to cycles.

A smaller study of the efficiency of cycle detection is reported in Guizhu et al., who used a simple pattern recognition technique to identify the passage of a number of cycles over an inductive loop (*21*). This information, along with information from vehicle flows in motorized traffic lanes, is used by a real-time traffic control system. An experiment carried out at a junction in Tianjin, China, gave a count accuracy of at least 85 percent. The technique has not been tested in a lane of mixed traffic.

URBAN TRAFFIC CONTROL

The control of traffic in the urban environment can range from a simple isolated junction running the same fixed-time signal plan all day to a sophisticated network of computer-controlled traffic-responsive signals taking information from detectors, roadside beacons, in-car systems, and other traffic infrastructure. Wood provides a comprehensive review of UTC systems, focusing primarily on adaptive systems (*22*).

When signals are used to control and manage traffic, practitioners have a number of related elements with which to work. The first is how the available green time is shared or split among the stages. The second is the length of the signal cycle, which can range from low values such as 20 s up through to a couple of minutes. The third component is the offset between junctions. Other elements may include which stages are run during a signal cycle and in which order the stages are run.

Fixed-Time Isolated Traffic Environment

In an isolated traffic environment the only suitable way of providing priority is through the split decision. To trigger a modification to the split optimizer, a detector that can selectively detect the cycle is required. If detection is possible, then a range of actions is possible. If the cyclist is predicted to reach the stop line just as or shortly after the signal is due to change from green, the change can be delayed by a sufficient number of seconds to allow the cyclist to travel through the junction. If, however, the prediction is too far beyond the end of green, then an earlier-than-envisaged recall of the green stage for cyclists—by means of running of the remaining stages at or near their minimum—would help to reduce cyclists' delay. This level of modification to the fixed-time signals may have potentially serious effects on the operation of the junction, and thus there may also be a requirement for payback mechanisms, or an inhibition on future priority calls for a number of signal cycles.

Where there is an advanced stop line at a junction that allows cyclists to position themselves at the head of the traffic queue or make an opposed turn, a form of reverse priority may be desirable. Such a scheme would ensure that when the cyclist reaches the stop line the signals should have been red for a short period of time, to allow motor vehicles to clear the reservoir box, and the signals should remain red for a reasonable amount of time so that the cyclist may safely maneuver within the box.

In a coordinated system of fixed-time traffic signals, the offsets between adjacent signals can have a significant effect on the journey times for vehicles. Cycles tend to travel at slower speeds than does motorized traffic, so an offset arranged for a motorized green-wave may be inappropriate. If, for instance, there is a large volume of cycle traffic along a sequence of signalized links and aiding this flow is thought to be desirable, the signal offsets along these sequences of links could be optimized for a cyclists' green-wave rather than one for the general traffic stream. A similar methodology has been applied in the past for buses (*23*). This form of consideration for cyclists can be achieved without the need for cycle detection. Taylor explores other offset strategies that optimize the progression requirements for both motorized and cycle traffic streams (*24*, Chapter 4).

Traffic-Responsive UTC Systems

Governments, local and city authorities, academics, and equipment manufacturers have devoted great effort to the development and implementation of traffic-responsive UTC systems. Complex systems have been produced, with data arriving from many sources and decisions made on many events. Cycling must stake a claim within this regime.

Many of the simpler measures outlined for fixed-time signals can be incorporated into a responsive UTC system with minor modifications. Simplified greatly, responsive systems can be classified as centralized or decentralized. With centralized systems, on-site information is passed back to a central location, which mediates on conflicting demands. In a decentralized system, control is distributed through the network, usually at the junction level, and communication with neighboring control units takes place.

European Experience

Within the United Kingdom there are a number of city and district authorities with large cycle commuting populations and installed UTC systems. Contacts with many of these authorities tend to suggest that only minor modifications are required in order to accommodate the impact of cyclists in their UTC systems. These minor modifications may range from the modification of lost-time parameters at the start or end of a stage, in order to allow for proper clearance for cyclists or the presence of an advanced stop line, to the running of demand-dependent stages when a cycling stage is required. A number of measures that relate to the general operation of UTC systems and that may have a beneficial effect on cyclists have been implemented or proposed by local authorities.

Offsets

In York the traffic signal engineers use "tail-end biasing" to optimize the offsets between signals on a route. This involves weighting offsets in an attempt to synchronize the tail ends of green times. This is primarily done to favor bus traffic (in particular, the Park and Ride services), but it has the effect of favoring all slower moving traffic, including cyclists. Feedback received from cyclists about this signal coordination has been positive.

Use of Fixed-Time Plans to Override SCOOT

The City of York Council is about to try this technique to "gate" traffic and allow longer green times for pedestrians, cyclists, and public transport at particular times of the day. This is still at the experimental stage, and there is some doubt about how this type of queue relocation technique may be received by motorists.

Use of SCOOT Detectors on Segregated Cycle Facilities

There is no overriding technical reason why SCOOT detectors cannot be placed near the entry to segregated cycle facilities and the segregated link modelled within SCOOT [as was the case in Beijing (*19*)]. Traffic would affect the downstream signals on the cycle facility in a way similar to the way general traffic affects downstream signals on a normal link. Cambridgeshire County Council is about to experiment with a dedicated SCOOT loop on a segregated cycle facility.

SCOOT Links

It would be possible to create a "dummy" link network—that is, extra links within the SCOOT model shadowing some or all of the existing SCOOT links. These would represent cycle travel between junctions (there would obviously have to be different travel times associated with these links). These links could then be weighted so that SCOOT gives extra consideration to cyclists in the general traffic stream. The authors are not aware of any location where this technique has actually been tried.

Detection

Detection of cycles in a general traffic lane is much easier by use of microwave detectors than it is by use of induction loops. This is important when vehicle-actuated control is used. The City of York Council now commonly uses microwave detectors on the approaches to signals. These can detect cyclists moving at 10 km/h (6.25 mph) or more (this is thought to be the great majority of cyclists).

Making journeys by cycle is much more common in continental Europe, especially in the Low Countries and parts of Scandinavia. In 1994, the Dutch city of Nijmegen installed a SCOOT UTC system to control an extensive network of traffic signals. The implementation of the system is discussed in Middelham et al. (*25*). The primary requirement was that the signal cycle time did not grow too large, since this may have had adverse effects on cyclists' safety and journey times. A companion paper by Middelham et al. gives a report on the assessment of the SCOOT system's performance relative to the existing well-maintained and updated fixed-time system known as STAR (*26*). For both private and public motorized traffic, SCOOT gave an increased throughput of traffic, but journey time differences were inconclusive. A separate assessment was made for a cycling commuter route between the city center and the university campus. The journey time for cyclists tended to show a consistent but not significant increase, a result attributed to the longer signal cycle times that SCOOT implemented. The effects on the journey time for cyclists crossing the commuter route were neutral, with the same number of junctions showing reductions as increases in journey time, although all differences were small.

Chinese Experience

There is an obvious need for cycle traffic to be considered when UTC systems are being implemented in China. In the major cities there is both a high proportion of cycling and cycle ownership. Liu et al. provide a study of cycle use in Beijing, and Xin gives a similar study of Shanghai (*27*, *28*). In terms of passenger trips, Beijing had 60 percent of urban trips by cycle in 1992, and Shanghai had 31 percent in 1986. As for ownership, Beijing had cycles constituting 94 percent of its registered vehicle fleet in 1989, and Hangzhou had 97 percent in the same year. Along with this high proportion of cycle use, there is also a high growth in travel and transport, with Beijing reporting a 16 percent annual growth rate for vehicles and 10 percent for cycles, and Hangzhou reporting 9 percent for cars and 12 percent for cycles.

During the mid 1980s the level of traffic volume and a high growth rate led the Beijing city authorities to consider the implementation of a UTC system in a section of the city. The system chosen was the SCOOT traffic control system (*19*, *29*).

The system is designed to give specific consideration to cycles traveling along a link physically separated from motorized traffic. Within the link, a 45 degree parallelogram-shaped loop was found to be more effective at detecting a cycle than was the traditional rectangular shape. The optimum horizontal width for this loop was found to be 1.1 m, which is the same as the average wheel base length of a cycle. Later studies carried out by Leschinski showed that, out of a study of four loop types, this arrangement performed well for cycle detection (*18*).

The position of the loop within the link was found to be a significant factor in the utility of the data provided. After a consideration of two options, one to place the detector at the entrance to the link and another to place it at the exit from the link, a third option was identified, that of placing the loop a short distance from the stop line. This provided for a compromise between the effective operation of the offset and split optimizers within SCOOT. A setback distance that made the journey time of a cycle correspond with that for cars traveling from the entry detector on the motorized link to its stop line was found to be ideal and typically resulted in a cycle detector 50 to 100 m before the stop line.

The team established a composite measure of cycle flow and occupancy called a Bicycle Link Profile Unit, which was capable of aggregation with the normal SCOOT Link Profile Unit. This enabled the cycle link to be incorporated into the standard SCOOT model in the same manner as were other links. Weighting functions are then available to advantage or disadvantage the cycle traffic stream relative to the motorized traffic stream.

Preliminary results following implementation suggest that the delay to motor vehicles has been reduced by 24 percent, whereas the reduction for cycle traffic is some 15 percent.

ASSESSMENT

One of the striking things about almost all the facilities and measures described in this paper is the lack of assessment in terms of numbers of cyclists affected, how they were affected, whether the route choice of cyclists was affected, or whether there were any effects on mode choice over the surrounding area. The reason for this is that discernment of any changes that are due to an isolated cycle facility is likely to be difficult.

Monitoring

The counting of cycle flows by automatic methods is possible (*17*), but because of low flows and the location of cyclists in the carriageway, these flow counts are not always accurate. The counting and classification of vehicles by manual methods can provide high-quality information in great detail, but such exercises are expensive and are not available on a medium-to-long-term basis.

Sharples provides a report of cycle flows along sections of roads in Manchester (*30*). Whereas the seasonal "shape" of traffic flows is well understood (more cycling takes place during the drier, sunnier summer months than during the cold, darker winter months), the flow profile through a typical day is less documented. The study concentrated on the volume profile for cycling through the day during October 1993 at five sites. The main conclusion was that the cycle flow was much more concentrated during the morning and evening peaks than was motorized traffic. This tends to support the hypothesis that cycles are mainly used for commuting purposes. The significance of this is that although the daily flow of cyclists may be low, these flows are disproportionately concentrated during the peak periods when UTC systems are most active in their control of the traffic demand.

A more recent study of cycle route choice is given in Sharples (*31*). Preference data were collected on cyclists' route choices in Edmonton, Canada, the Heathrow area, and the Elephant and Castle gyratory; both of the latter are in London. The final section lists those considerations that were found to be of importance to most cyclists as they determined their route choices. These considerations were access to destination, route knowledge, distance and time, ease of travel, safety, comfort, and experience.

Modeling of Cycling

Computerized models capable of modeling cycling have only recently become available for use. An overview of such models is given in Sharples (*32*). The use of four models is highlighted: QUOVADIS-BIKE, SATURN, EMME/2, and TRIPS/START. Most of these packages are not cycle specific but can have their normal expected values for certain parameters modified to account for the characteristics of cyclists.

A general discussion of how these models can be adapted is provided. Considerations include the structure of the road network, definition of origin-destination zones, highway and cycleway links, estimation of trip matrices, route choice objectives, choice of assignment algorithm, and cyclists' speeds.

An adequately calibrated cycle traffic assignment model can be of use to engineers designing cycle-friendly facilities. They can identify locations where there are relatively large flows of cyclists and concentrate their attention at those sites. They can also identify routes with a network favored by cyclists and design a route-based strategy that would aid the complete journey, from origin to destination, for a cyclist [Rickman gives details for such an application in Ipswich (*33*)]. Such models have also been used to identify the potential for a mode switch out of cars and onto cycles for short-distance journeys of less than 5 to 7 km in Amersfoot, Holland (*34*).

A real-time control of traffic in a model of a traffic network can be achieved using microsimulation models. In its review of microsimulation models, the SMARTEST project team identified only two of the thirty microsimulation models it reviewed as claiming to be able to represent bicycles (*35*). Fortunately, both packages mentioned (FLEXSYT II and HUTSIM) are capable of being connected to UTC systems for evaluation purposes. A third simulator, SIGSIM, is claimed to be able to represent motorbikes, which do possess some characteristics similar to those of cycles.

CONCLUSIONS

Limited European evidence would suggest that there is little need to explicitly take account of cycling when implementing a UTC system. The usual modifications required tend to be either accounting for the physical nature of any cycling measure or accounting for the journey characteristics of cyclists. This tends to suggest that cyclists can be given a high degree of consideration within a UTC system without adding any significant additional costs. This low level of expenditure is even the case in Holland, where cycling accounts for nearly 27 percent of all trips. Only when cycling achieves a near-dominant proportion of the trips within a city and is growing in volume, as in China, is explicit consideration of cyclists required. To fail to do so in this latter situation would not only produce an inefficient UTC system but also a potentially dangerous one.

Many of the strategies to aid cycling require the selective detection of individual cycles traveling in a mixed stream of traffic. Unfortunately, detection can only be reliably achieved by use of specialist equipment and in a segregated lane. The potential manufacturers of the more useful equipment that is capable of detecting and distinguishing cyclists in a general stream of traffic are unlikely to develop such devices until there is a demand for them. Thus there is a Catch-22 situation in which there are no facilities because there are no devices, and there are no devices because there are no facilities that require these devices. The ideal would be an ability to accurately measure the volume of cyclists and gather information that could then be used for both operational and monitoring purposes.

If individuals are to be encouraged to adopt cycling as a mode of transport, then either the alternatives need to become unattractive or cycling needs to become more attractive. The best way of making cycling more attractive is the implementation of high-profile measures, which tend to be physical in nature and have a high visual impact, and which will increase the safety or the perception of safety by cyclists. UTC systems alone cannot deliver this, but they can be packaged with physical measures in order to achieve this aim. UTMC systems are a further step in the right direction, as they are more concerned with wider traffic management and transport policy issues than UTC systems historically have been.

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REFERENCES

1. U.K. Department of Transport. *The National Cycling Strategy*. HMSO, London, United Kingdom, 1996.
2. U.K. Department of the Environment, Transport, and the Regions. *A New Deal for Transport: Better for Everyone*. HMSO, London, United Kingdom, 1998.
3. U.K. Department of the Environment. *The United Kingdom National Air Quality Strategy*. HMSO, London, United Kingdom, 1997.
4. Routledge, I., S. Kemp, and B. Radia. UTMC: The Way Forward for Urban Traffic Control. *Traffic Engineering and Control*, Vol. 37, No. 11, November 1996, pp. 618–623.
5. Smith Group Limited. *UTMC Web Site*. http://www.utmc.org.uk/utmc/. Accessed March 21, 2000.
6. *Barriers to Cycling: Perspectives from Existing and Potential Cyclists*. C-PAG, Godalming, Surrey, United Kingdom, 1997.
7. *Cycling Motorists: How to Encourage Them*. Automobile Association Group Policy Division, Basingstoke, Hampshire, United Kingdom, 1996.
8. Institution of Highways and Transportation. *Cycle Friendly Infrastructure: Guidelines for Planning and Design*. Cyclists Touring Club, Cotterell House, Godalming, Surrey, United Kingdom, 1996.
9. CROW. *Sign Up for the Bike: Design Manual for a Cycle-Friendly Infrastructure*. Center for Research and Contract Standardization in Civil and Traffic Engineering, Netherlands. 1993
10. Edinburgh City Council. *Cycle Friendly Design Guide*. City Development, Edinburgh, United Kingdom, 1997.
11. U.K. Department of Transport and Department of the Environment, Transport, and the Regions. *Traffic Advisory Leaflets*. Traffic Advisory Unit Publications, London, United Kingdom. http://www.roads.detr.gov.uk/roadnetwork/ditm/tal/. Accessed March 23, 2000.
12. Ryley, T. J. *Transport Research Laboratory Report 181: Advanced Stop Lines for Cyclists: The Role of Central Cycle Lanes and Signal Timings*. Transport Road Research Laboratory, Crowthorne, Berkshire, United Kingdom.
13. Bretherton, R. D., K. Wood, and G. T. Bowen. SCOOT Version 4. In *Proc., 9th International Conference on Road Transport Information and Control*, Institution of Electrical Engineers, London, United Kingdom, 1998, pp. 104–108.
14. Allot and Lomax. *Cyclists and Roundabouts. A Review of Literature*. Cyclists Touring Club, Cotterell House, Godalming, Surrey, United Kingdom, 1991 and 1993.
15. Lines, C. J. Cycle Accidents at Signalized Roundabouts. *Traffic Engineering and Control*, Vol. 36, No. 2, February, 1995, pp. 74–77.
16. Morgan, J. M. *Transport Research Laboratory Report 395: Roundabouts in Continental Europe Designed with Cycle Facilities or 'Cycle Thinking'*. Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom, 1997.
17. Davis, D. G., P. Emmerson, and A. Pedler. *Transport Research Laboratory Report 395: Guidance on Monitoring Local Cycle Use*. Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom, 1999.
18. Leschinski, R. Evaluation of Inductive Loops for Bicycle Detection. *17th ARRB Conference*, Gold Coast, Queensland, Australian Research Board, Victoria, Australia, 1994.
19. Wood, K., R. D. Bretherton, and D. Li-Ren. Bicycle SCOOT in Beijing. Urban Transport and Urban Management in Developing Countries. *Proc., 16th PTRC Transport and Planning Summer Annual Meeting*, Vol. P310, 1988, pp. 29–38.
20. Maki, P. J., and P. S. Marshall. Accommodating Bicycles at Signalized Intersections with Loop Detectors: A Case Study and Example. *Proc., 67th Annual Meeting of the Institute of Transportation Engineers*, Boston, Mass., 1997.
21. Guizhu, W., C. Zongfa, and L. Xu. Induction Loop Detection of Bicycles Based on Pattern Recognition Techniques. In *Transportation Systems: Theory and Application of Advanced Technology*, Vol. 1, 1995, pp. 31–36.
22. Wood, K. *Project Report 41: Urban Traffic Control, Systems Review*. Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom, 1993.
23. Robertson, D. I., and R. A.Vincent. *Laboratory Report 666: Bus Priority in a Network of Fixed-Time Signals*. Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom, 1975.
24. Taylor, D. *Contributions to Bicycle-Automobile Mixed-Traffic Science: Behavioral Models and Engineering Applications*. Ph.D. dissertation. The University of Texas at Austin, 1998.
25. Middelham, F., J. Dibbits, and W. Fransen. The Implementation of SCOOT in Nijmegen in the Netherlands. *Proc., Road Traffic Monitoring and Control* Conference, London, England, 1994, pp. 125–130.
26. Middelham, F., H. Taale, J. Dibbits, and W. Fransen. The Assessment of the SCOOT in Nijmegen. *Proc., Road Traffic Management and Control Conference,* 1996, pp. 66–70.
27. Liu, X., L. D. Shen, and J. Huang. Analysis of Bicycle Accidents and Recommended Counter Measures in Beijing, China. In *Transportation Research Record 1487*, TRB, National Research Council, Washington, D.C., 1995, pp. 75–83.
28. Xin, C. J. Bicycle Transportation in Shanghai: Status and Prospects. In *Transportation Research Record 1563*, TRB, National Research Council, Washington, D.C., 1996, pp. 8–15.
29. Peck, C., P. T. W. Gorton, and D. Li-Ren. The Application of SCOOT in Developing Countries. *Proc., 3rd International Conference on Road Traffic Control*, 1990, pp. 104–109.
30. Sharples, R. Cycle Flows by Time of Day on Urban Highways. *Traffic Engineering and Control*, Vol. 38, No. 11, November 1997, 1997, pp. 607–609.

31. Sharples, R. The Use of Main Roads by Utility Cyclists in Urban Areas. *Traffic Engineering and Control*, January 1999, 1999, pp. 18–22.
32. Sharples, R., Cycle Modeling—An Overview. *Traffic Engineering and Control*, April 1999, pp. 209–211.
33. Rickman, M., Effective Cycle Route Planning—The Application of Modeling Techniques to the U.K. *Proc., Velo-City Conference*, Basel, Switzerland, 1995.
34. Wassink, B. J. QUOVADIS-BIKE: The Bicycle Model. *Proc., Velo-City Conference*, Basel, Switzerland, 1995.
35. Algers, S., E. Bernauer, M. Boero, L. Breheret, C. Di-Taranto, M. S. Dougherty, K. Fox, and J. F. Gabard. Review of Micro-Simulation Models. *SMARTEST Project Deliverable D3*, Institute for Transport Studies, University of Leeds, Leeds, United Kingdom, 1997.

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