Progressive Signal System in a Network of Arterial Streets

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Computer-aided systems to coordinate traffic signals on urban roadways have been developed to achieve a smooth flow of traffic uninterrupted by the red phase of the signals. Most of these systems, however, have neglected one or more of the important traffic variables and their interrelationships and therefore may produce timing patterns, which, when implemented under certain traffic conditions, may not reduce vehicle stoppages and delays.

A new model, the traffic signal optimization model (TRASOM), has been developed that considers the three basic traffic variables: speed V, volume Q, and density K. The model allows different road segments to have different Q-K-V relationships because traffic flow depends not only on the geometrics of the road but also on the environment and traffic conditions. Because the Q-K-V relationship defines roadway capacity as a function of speed, this relationship is an essential factor in the proper design of a progressive signal system. The effect of this relationship on the design of the optimum timing plan becomes increasingly critical as the volume increases. By using a characteristic V-Q relationship as an added constraint in determining a progressive speed, one can produce a solution that is consistent with observed flow characteristics and that avoids those solutions that are infeasible.

TRASOM has two major advantages: (a) a guarantee of a feasible product and (b) a method for measuring and expressing incremental improvements in system performance. The variables and constraints used in this model include the following:

1. Independent variables (traffic arrival rate and distribution, lane usage, roadway geometrics and conditions, and service rates and function);
2. Dependent variables (traffic throughput, progression speed, concentration, total and average delay, queue characteristics, and system efficiency);
3. Control variables (cycle lengths, cycle splits, and offsets); and
4. Imposed constraints (pedestrian crossing time, maximum and minimum red time, V-Q red time, and maximum and minimum cycle lengths).

The objective of TRASOM is to search for the combination of control variables that results in the optimum set of dependent variables within the given constraints. The measures of performance in this decision-making process may include percentage of throughput, progression speed, travel time, average and total delay, queue characteristics for left-turning traffic, or any combination of such variables. The minimization of average network delay is an objective function used in the model.

TRASOM first determines optimal linear solutions for all the roadways constituting the network and then fits in the intersecting nodal offsets according to a sequential strategy. The linear optimal solution thus establishes the optimal progressive traffic flow on each roadway rather than obtaining flow through individual links at various progression speeds.

For system optimization, each linear system in the street network is rank ordered on a priority system. The assigned priorities do not change the cycle splits; however, they do establish the sequence used in determining feasible network solutions. A linear system with no or only one higher priority system crossing it retains the optimal timing plan it would have had as a single street. Any linear street crossed by two or more streets with higher priorities may not retain its optimal linear solution because new solutions are obtained for these intersections that treat the offsets as fixed. If, following the network analysis, there is no feasible solution for one or more linear streets for a particular cycle length and set of constraints, there will be no solution produced for the entire network for that cycle length unless specifically requested by the analyst.

A feasible solution for each cycle length tested is printed for the convenience of the analyst and is followed by summary statistics or expected traffic performance characteristics produced by performing macrosimulation and other analysis based on the designed cycle length, offsets, and splits. The output format identifies the signal numbers, names of cross streets, distances between intersections, approach volumes, and rank-ordered priority of all the cross streets for each linear system. Summary statistics include expected left-turning queue length for all approaches, average delay at all approaches, average number of stopped vehicles at each intersection and average percentage of throughput on the main street. The optimum network solution for a given demand is then determined by comparing the system attributes for the optimal solution at each cycle length.

TRASOM requires the following input data: distance between intersections, intersection counts, lane usage, turning movements, roadway capacity, speed and volume data at selected sections of roadway, and roadway geometrics. Any special features, such as multiphase signals, special left turn phase, and special turning prohibitions, can also be incorporated into the model.

The TRASOM program is written in FORTRAN IV and is capable of describing timing patterns for various network sizes. Recent projects have ranged from a 20-signal linear street to a 93.24-km^2 (36-$mile^2$) area containing 200 signals. Compared to other computer-aided systems, TRASOM has simple data requirements, an output that is easy to interpret, and small implementation costs.