CONTRIBUTION TO THE VEHICLE TRAFFIC CONTROL

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Abstract **–Regarding the urban traffic fluidization, the author initiate investigation concerning the analyzing, supervising and monitoring the public vehicle traffic with the purpose of rising the quality of the public transportation service and diminish the pollution.**

One of the problems discussed in this paper trough these research is the presentation of some aspects related to the traffic control systems. The theoretical presentation is finalized by a practical proposal which cover whole aspects of the problematic urban traffic control. The solution presented in this paper can be applied to every intersection.

Keywords**:** *traffic, control system, vehicle, urban traffic, intersection*

1. INTRODUCTION

Transportation has always been a crucial aspect of human civilization, but it is only in the second half of this century that the phenomenon of traffic congestion has become predominant due to the rapid increase in the number of vehicles and in the transportation demand in virtually all transportation modes. Traffic congestion appears when too many vehicles attempt to use a common transportation infrastructure with limited capacity. In the best case, traffic congestion leads to queuing phenomena (and corresponding delays) while the infrastructure capacity ("the server") is fully utilized. In the worst (and far more typical) case, traffic congestion leads to a degraded use of the available infrastructure (reduced throughput that may even lead to a fatal gridlock) with excess delays, reduced safety, and, recently, increased environmental pollution.

The emergence of traffic (i.e. many interacting vehicles using a common infrastructure) and subsequently traffic congestion (whereby demand exceeds the infrastructure capacity) have opened new innovation needs in the transportation area. The energy crisis in the 1970's, the increased importance of environmental concerns, and the limited economic and physical resources are among the most important reasons why a brute-force approach (i.e., the continuous expansion of the available transportation infrastructure) cannot continue to be the only answer to the ever increasing transportation and mobility needs of modern societies. The efficient, safe, and less polluting transportation of persons and goods calls for an optimal utilization of the available infrastructure via suitable application of a variety of traffic control measures. This trend is enabled by the rapid developments in the areas of communications and computing, but it is quite evident that the efficiency of traffic control directly depends on the efficiency and relevance of the employed control methodologies. This chapter will provide an overview of advanced traffic control strategies for three particular areas: Urban road networks, freeway networks, and route guidance and information systems.

2. THE BASIC ELEMENT OF A CONTROL SYSTEM

The traffic flow behavior in the network depends on some external quantities that are classified into two groups (figure 1):

- *Control inputs* that are directly related to corresponding control devices such as traffic lights, variable message signs, etc; the control inputs may be selected from an admissible control region subject to technical, physical, and operational constraints.
- *Disturbances,* whose values cannot be manipulated, but may possibly be measurable (e.g. demand) or detectable (e.g. incident) or predictable over a future time horizon.

The network's output or performance is measured via suitable indices, such as the total time spent by all vehicles in the network over a time horizon. The task of the *surveillance* is to enhance and to extend the information provided by measurement devices (e.g. loop detectors) as required by the subsequent control strategy and the human operators. The kernel of the control loop is the *control strategy*, whose task is to specify in real time the control inputs, based on available measurements/estimations/predictions, so as to achieve the pre-specified goals (e.g. minimization of total time spent) despite the influence of various disturbances.

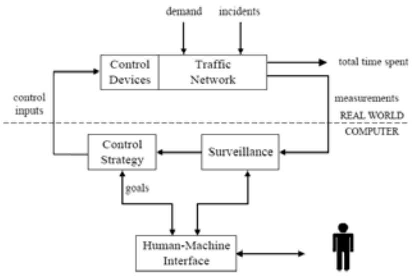

Figure 1: The basic elements of a system control

In an automatic control system, this task is undertaken by an algorithm (the control strategy). The relevance and efficiency of the control strategy largely determines the efficiency of the overall control system. Therefore, whenever possible, control strategies should be designed with care, via application of powerful and systematic methods of optimization and automatic control, rather than via questionable heuristics.

For the needs of this chapter we will use a discrete-time representation of traffic variables with discrete time index k = 0, 1, 2, … and time interval T. A *traffic volume* or *flow* q(k) (in veh/h) is defined as the number of vehicles crossing a corresponding location during the time period [kT, (k+1)T], divided by T. *Traffic density* ρ(k) (in veh/km) is the number of vehicles included in a road segment of length ⊗ at time kT, divided by ⊗ . *Mean speed* v(k) (in km/h) is the average speed at time kT of all vehicles included in a road segment.

We consider a traffic network (figure 2) that receives demands $d_i(k)$ (in veh/h) at its origins i = 1, 2, … and we define the total demand $d(k) = d_1(k) + d_2(k) + \dots$ We assume that d(k), k = 0, …, K, is independent of any control measures taken in the network. We define exit flows $s_i(k)$ at the network destinations i = 1, 2, …, and the total exit flow $s(k) = s_1(k) + s_2(k) + \dots$ We wish to apply control measures so as to minimize the total time spent T_s in the network over a time horizon K, i.e.

$$T_s = T\sum_{k=0}^{K} N(k) \qquad (1)$$

where N(k) is the total number of vehicles in the network at time k. Due to conservation of vehicles

$$N(k) = N(k-1)+T[d(k)-s(k)] \qquad (2)$$

$$N(k) = N(0) + T\sum_{k=0}^{k-1}[d(k) - s(k)] \qquad (3)$$

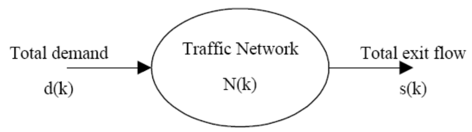

Figure 2: Input and output variables of a intersection

Substituting equation (3) in equation (1) we obtain

$$T_s = T\cdot\sum_{k=0}^{K}[N(0) + T\cdot\sum_{k=0}^{k-1} d(k) - T\cdot\sum_{k=0}^{k-1} s(k)] \qquad (4)$$

The first two terms in the outer sum of equation (4) are independent of the control measures taken in the network; hence minimization of T_s is equivalent to maximization of the following quantity

$$S = T^2\cdot\sum_{k=0}^{K}\sum_{k=0}^{k-1} s(k) = T^2\sum_{k=0}^{K-1}(K-k)\cdot s(k) \qquad (5)$$

Thus, minimization of the total time spent in a traffic network is equivalent to maximization of the time-weighted exit flows. In other words, the earlier the vehicles are able to exit the network (by appropriate use of the available control measures) the less time they will have spent in the network.

3. PUBLIC ROAD TRAFFIC CONTROL

Traffic light at intersections is the major control measure in road networks. Traffic lights were originally installed in order to guarantee the safe crossing of antagonistic streams of vehicles and pedestrians. With steadily increasing traffic demands, it was soon realized that once traffic lights exist, they may lead (under equally safe traffic conditions) to more or less efficient network operations, hence there must exist an optimal control strategy leading to minimization of the total time spent by all vehicles in the network.

Although the corresponding optimal control problem may be readily formulated for any road network, its real-time solution and realization in a control loop like the one of Figure 1 faces a number of apparently insurmountable difficulties:

- The red-green switches of traffic lights call for the introduction of binary variables, which renders the optimization problem combinatorial.
- The size of the problem for a whole network is very large.

− Many unpredictable and hardly measurable disturbances (incidents, illegal parking, pedestrian crossings, intersection blocking, etc.) may perturb the traffic flow.

− Measurements of traffic conditions are mostly local (via loop detectors) and highly noisy due to various physical effects.

− There are tight real-time constraints, e.g. decision making within 2s for advanced control systems.

The combination of these difficulties renders the solution of a detailed optimal control problem infeasible for more than one intersection. Therefore, proposed control strategies for road traffic control introduce a number of simplifications of different kinds or address only a part of the related traffic control problems. An intersection consists of a number of approaches and the crossing area. An approach may have one or more lanes but has a unique, independent queue. Approaches are used by corresponding traffic streams (veh/h). A *saturation flow* s is the average flow crossing the stop line of an approach when the corresponding stream has right of way and the upstream demand (or the waiting queue) is sufficiently large. Two *compatible* streams can safely cross the intersection simultaneously, else they are called *antagonistic*. A *signal cycle* is one repetition of the basic series of signal combinations at an intersection; its duration is called *cycle time* c. A *stage* (or *phase*) is a part of the signal cycle, during which one set of streams has right of way (figure 3). Constant *lost times* of a few seconds are necessary between stages to avoid interference between antagonistic streams of consecutive stages (figure 4).
There are four possibilities for influencing traffic conditions via traffic lights operation:

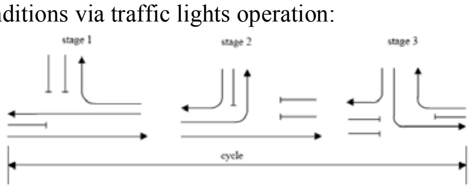

Figure 3: Example of signal cycle.

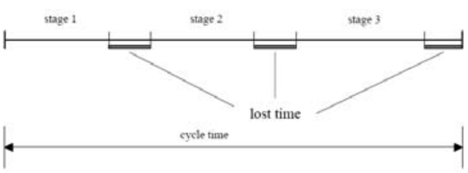

Figure 4: Cycle time and lost times.

− *Stage specification*: For complex intersections involving a large number of streams, the specification of the optimal number and constitution of stages is a non-trivial task that can have a major impact on intersection capacity and efficiency.

− *Split*: This is the relative green duration of each stage (as a portion of the cycle time) that should be optimized according to the demand of the involved streams.

− *Cycle time*: Longer cycle times typically increase the intersection capacity because the proportion of the constant lost times becomes accordingly smaller; on the other hand, longer cycle times may increase vehicle delays in under saturated intersections due to longer waiting times during the red phase.

− *Offset*: This is the time difference between cycles for successive intersections that may give rise to a “green wave” along an arterial; clearly, the specification of offset should ideally take into account the possible existence of vehicle queues.

Control strategies employed for road traffic control may be classified according to the following characteristics:

− *Fixed-time strategies* are derived off-line by use of appropriate optimization codes based on historical constant demands for each stream for a given time-of day; *traffic-responsive strategies* make use of real-time measurements (typically one or two loops per link) to calculate in real time the suitable signal settings.

− *Isolated strategies* are applicable to single intersections while *coordinated strategies* consider an urban zone or even a whole network comprising many intersections.

− Some strategies are only applicable to *under saturated* traffic conditions, whereby vehicle queues are only created during the red phases and are dissolved during the green phases; other strategies are adapted also for *oversaturated* conditions with partially increasing queues that in some cases may even reach the upstream intersection.

4. DEVELOPMENT OF AN AUTONOMOUS ADAPTIVE TRAFFIC CONTROL SYSTEM

The basic structure of the proposed system includes a number of intersection controllers. One intersection controller is placed at each intersection and performs all functions and computations required at the intersection. These controllers are connected to a dedicated communication network, trough which the controllers share information in order to remain synchronized. The intersection controllers may be connected also to a central computer. For the system basic function, which is traffic conditioning, only the intersection controllers are required. The connection to the central computer is optional and is needed only for system surveillance and for traffic data collection and storage. The functions that a system intersection controller performs are the following: it reads the detectors' state and hence it computes traffic flow information, it computes the timing schedule for the intersection based on traffic flow, it communicates with the controllers of the adjacent nodes to share data and synchronization information, it switches traffic lights on and off and finally it checks the system for malfunctions. The block diagram of an intersection controller is shown in figure 5.

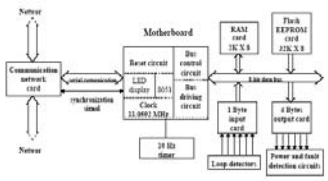

Figure 5: The block diagram of an intersection controller

As shown, the controller consists of a motherboard and a number of cards connected to it. The heart of the motherboard is the microcontroller. On the motherboard there is an 8-bit bus which connects extension cards. Thus, for each particular traffic node, only the necessary cards need to be connected to the bus. There are four kinds of extension cards: RAM, ROM, input and output. Input and output cards are used whenever input or output is required for the system. The main purpose of input cards is for reading the loop detectors (Colpitz sensors), while the output cards are used for driving the power circuits that switch traffic lights on and off. As shown in the block diagram of figure 5, the power circuits have also the ability to detect faults in the lamps. This feature is very important for an intersection controller. In addition to the above, there is a communication card which is connected directly to the microcontroller rather than to the bus.

4. CONCLUSIONS

To find a solution for a transport problem it has to be considered a series factors:

- Type of network;
- The traffic elements which affect the vehicle traffic;
- Kinds and numbers of sensors used to acquire all needed information from the traffic;
- Weather conditions;
- Unforeseeable situations which can appear in traffic.

In conclusion, has been started the research work for developing a specific traffic strategy for Craiova and carrying out a monitoring system for public vehicles, the target of this project being reducing the total time of travel.

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