

OPTIMISING OFFSETS AND BANDWIDTHS IN TRAFFIC NETWORKS

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Executive Summary

The optimisation of offsets in traffic signalisation has been considered. Cycle times, phase splits and phase sequences were assumed fixed. Arterial roads were focussed upon as they are deemed more important than full traffic networks. Analytical expressions were defined for computing bandwidths between adjacent intersections, and are a function of the offsets. An optimisation model for selecting offsets across an arterial was proposed and utilises a weighted bandwidth objective. A generic optimisation-simulation approach was proposed to refine an initial starting solution according to a specified metric. A metric that reflects the number of stops and the distance between stops was proposed to explicitly reduce the dissatisfaction of road users and to implicitly reduce fuel consumption and emissions. Conceptually the optimisation-simulation approach is superior as it can handle real-life complexities and is a global optimisation approach. It can be extended easily for other advanced features and is a robust and “established” technique.

Background Information

Traffic signalisation is a regulated mechanism to control the movement of large numbers of vehicles on road networks. Traffic signals are positioned at road intersections to stop collisions (i.e. conflicting traffic movements) from occurring on intersecting paths; otherwise they are used to separate and improve (i.e. smooth) the flow of vehicles. Signal control strategies are manifested as cycle times, phase splits and offsets. Each phase is associated with the movement of traffic through the intersection from a specific direction (i.e. a green period). The time to perform “green” periods for all the phases at an intersection is the cycle time. Each phase has a cycle of red, green and yellow lighting that is repeated. The time for each of these periods is not necessarily the same; this is dictated by the phase split. Offsets are a measure of the “time” difference of the beginning of successive “green” periods between adjacent intersection phases.

Research Trends

Genetic algorithms are very popular as an optimisation technique for signalisation. Other meta-heuristics seem not to have been applied. Evolutionary approaches which are superior to GA, have not been applied either. There is few full scale systems developed from academic research, RHODES is the exception. Almost all the approaches are not adaptable to real time traffic conditions. The choice of simulation tool and performance metric is variable, i.e. matter of personal preference and not scientific reasoning. Analytical approaches feature quite regularly but simulation (coupled with an optimisation strategy) is most prominent.

Performance Criterion

Numerous metrics can be used for the optimisation of offsets. Political and psychological perspectives seem to be quite dominant when selecting a metric. Four metrics are suggested for further investigation:

Z_1 minimises weighted average delays across the network, which is a measure for travel time.

Z_2, Z_3 minimises weighted stops, which is a measure of driver dissatisfaction and fuel consumption.

Z_4 maximises the weighted distance between stops, which is a measure for “green flow” perception.

Combinations of these metrics also lead to viable future approaches. The purpose of the first criterion is to reduce the travelling time of all drivers in the network. This metric “in theory” ensures that the delays experienced by drivers are minimal and throughput in the network is maximal. The first metric provides solutions that drivers often perceive as poor because it does not address the inconvenience of stopping at lights. The other metrics attempt to minimise this inconvenience and the resulting dissatisfaction. For example, drivers are perceived to be happier if there are fewer stops and the distance between stops is greater.

Bandwidth Quantification

Several competing approaches were developed. The different approaches are somewhat different (analytical, excel spreadsheet, etc). Further testing and validation of these approaches is necessary.

A valid analytical expression is “essential” and is to be used in an optimisation model. Bandwidth occurs between green phases at adjacent intersections. In essence this is then a *comparison of two time intervals*, each starting and ending at computable times. It has come to light that ten general cases result and should allow bandwidth to be quantified more generally, and easily.

Suggestion: A Bandwidth Optimisation Model

The bandwidth between adjacent intersections is a static function of those intersections offsets; it does not involve intersections further away in the network. In response, a simple and straightforward optimisation model is proposed. This model should be solvable instantly. This model requires a valid function for bandwidth otherwise invalid results will be obtained. The model’s objective function is weighted bandwidth. The model attempts to balance the bandwidth over all sections of road, in each travel direction and for each phase. The proposed model can handle the inherent complexities caused by “overlapping” offsets, and can “conceptually” provide the best “trade-of” solution across the entire network (or arterial). Further implementation and testing is needed.

Suggestion: General Optimisation and Refinement Approach

A general approach is proposed to refine a current non-optimal starting solution and to find the optimal traffic signal timings. This approach is advocated as it can find a globally optimal solution. This approach is computationally more expensive (i.e. takes more CPU time) however it can be made to run fast with careful encoding. Simulation is again suggested as a means of evaluating the effectiveness of traffic control timings. It is suggested that a fast simulation approach (cellular automata was suggested) is used, that can be run within a fraction of a second and at most 1 or 2 seconds. This allows multiple simulations runs and allows more accurate statistics to be collected.

Optimisation Techniques

Standard Linear Programming (LP)/ Integer Programming (IP) techniques can be used to solve the first optimisation model. A commercial solver like CPLEX is necessary. The integrated optimisation-simulation approach must be solved using meta-heuristics or similar approaches. Evolutionary (EA) and Simulated Annealing (SA) are well known, and can be implemented relatively easily. EA is a population based approach whereas SA refines a single solution. EA and SA give good performance with standard control parameters. Improved performance however is obtainable if control parameters are optimised.

Conclusions

Further testing is necessary to identify whether analytical equations for bandwidth are valid and sufficient. Implementation of the proposed optimisation techniques is necessary and these will need to be refined and tested during implementation. Further development time may be needed to implement a “fast” simulation tool.

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