ADVANCED TRAFFIC MANAGEMENT SYSTEM - AN ELEMENT OF MOTORISTS INFORMATION AND ADVISORY MESSAGE STRATEGY: A CONCEPTUAL FRAMEWORK TO SOLVE PROBLEMS OF TRAFFIC CONGESTION ON HEAVILY RECREATIONAL CORRIDORS.

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INTRODUCTION

The weekday and weekend traffic on our roads in NSW is often characterised by severe congestion, especially to Sydney CBD. Hot summer days and large engines idling while in a queue, produce overheated engines and overheated motorists.

Recreational travel is characterised by motorists venturing into regions of the state and country with which they are somewhat less familiar than their home town. In travelling to and from work, generally on the same route everyday, motorists have a higher probability of knowing what points will be trouble spots. The motorists are familiar with and can better anticipate the hours and the days traffic will be especially troublesome. In large cities, several, if not all radio stations frequently give information on traffic conditions throughout the entire metropolitan area. In fact, radio stations invest in helicopters, and announcers often specialise exclusively in conducting traffic surveillance in the peak hours. Recreational travellers seldom get a fraction of this service.

The motorist travelling to and from work generally tunes in on one radio station at some point and sticks with it for an extended period of time. If not, he/she quickly becomes familiar with what stations are available and what their relative merits are. Recreational travellers, on the other hand, are not familiar with what stations are available or whether any information useful to them is being given to any of the local stations, since they usually cater to local interests. The relative strength of local radio stations requires drivers to frequently re-tune their car radios. This exercise can be frustrating. Furthermore, a large proportion of urban radio stations today are FM stations having the advantage of very little interference. FM stations are generally limited by line-of-sight transmission ranges so that the recreational traveller will have to rely largely on AM stations. Increased interference may lead some motorists to turn the radio off completely.

There is an apparent need to have systematic and reliable information distributed to motorists in heavily travelled recreational corridors such as the North Sydney Corridor. Local entrepreneurs are not likely to fill this need because the out-of-town motorist is often regarded as a nuisance. There is little reason to provide any service beside fast food, gas and other necessities. The urban radio stations serve their clientele during their home-to-work trips, but the home-to-remote-recreation trip attracts little attention from commercial radio. Further, the more vehicles that are queued, the longer the time required to restore a route to an acceptable level of service. Once a roadway facility suffers a severe depression in level of service(high flow rate and operating speed corresponds to good level of service) acceptable conditions are not increase, the restoration of an acceptable level is very difficult. It is far more productive to avoid severe congestion, if at all possible.

It should be noted that the advantages in avoiding congestion create the need to predict when and where it will occur. The proximity of this bottleneck to the large metropolitan trip generators made congestion detection and information distribution rather quick. When congestion occurred and was made known to the public, the response time to reduce the generation of eastbound trips was short.

A significant potential exists to serve travellers by advising them as early as possible what quantity of traffic demand is currently being detected on the various routes and what conditions are expected to result as well as what current conditions prevail. Given accurate and reliable information, motorists will minimise travel time and discomfort, which will simultaneously tend to optimise the efficiency of the highway system.

POTENTIAL SOLUTION

One set of strategies to alleviate congestion might involve motorists using several highway facilities and providing information to motorists regarding current traffic conditions on these routes. Based on such information, motorists can determine which route offers them the best travel conditions and will minimise their travel time. Minimising the travel time of the motorist is strongly associated with maximising the efficiency of the roadway facilities. Distributing information may influence departure times as well as route selection for some motorists.

The success of this strategy depends on many factors, such as the accuracy and reliability of the information provided to the motorists, the effectiveness of the method of message transmission, and the manner in which as well as the consistency with which the motorists respond to advisory messages. These and other factors present many uncertainties for the State Highway Administration decision-maker who must evaluate traffic conditions and provide timely and accurate information and advisory messages to motorists who then must decide their best course of action to minimise travel time.

Transmitting information to motorists can be accomplished in several ways. Highway advisory radio, portable or permanent variable message signs, and commercial radio are candidate media. The most appropriate one or combination will be selected based on the availability of the media and the resources of the project at the appropriate time in the project.

DEFINE SYSTEM AND DESCRIBE RELATIONSHIPS

The purpose of the paper is to determine what motorist information and advisory message strategy would be most effective in reducing congestion. The quantification of relationships will be accomplished with standard statistical methods.

Relating travel patterns at various point on various routes on a system of highway facilities, require that the system be thoroughly and accurately defined. The system boundaries must be defined so that the corridor users can be identified as early as possible.

An attempt should be make to determine the relationship of system variables where cause-and-effect or rational association is a reasonable assumption. Preliminary examination of descriptive statistics for various parts of the system will yield initial system relationships that can be quantified more comprehensively through more thorough analyses.

OPTIMISE SYSTEM

The analysis of information and advisory message strategies should be undertaken after the system relationships are determined. System relationships should be stated, i.e. the interdependency of volume at various points over time, the response of motorists to information and advisory messages on volumes at various points over time. A set of strategies or policies will be established based on the stated relationships to minimise congestion and delay while optimising total volume. Tools that will be used to find the optimal operating conditions of the system with regard to volume and delay, include linear programming and dynamic programming. Depending on the level of detail in an analysis, dynamic programming may be an impractical tool outside the laboratory. Similarly, linear programming has practical limitations on the number of variables and constraints that can be included in a system analysis. Very detailed and complicated models frequently do not provide any more useful results than more simple representations.

Although a detailed conceptualisation of the system is necessary to define system relationships, the end product should be targeted to be as simple a model as possible.

The solution to traffic congestion problems involves determining what the response to given information will be by motorists. Information strategies must integrate traffic demand prediction and motorist response prediction, in order to optimise traffic allocation to alternate routes.

Correlation analysis and least-squares regression should be used where appropriate to predict demand and response. These predictions can be used to select information and advisory message strategies that will optimise the throughput on the alternate routes in the system.

DETERMINE OPTIMAL ALLOCATION OF TRAFFIC TO ALTERNATE ROUTES

Linear programming should be applied as an initial step in optimising traffic allocation to alternate routes. The objective function or measure of effectiveness may be maximising vehicle-kilometres per hour of travel for the system of fixed routes of equivalent lengths. This implies that travel time will be minimised. Distortions in modelling, such as maximising vehicle-kilometres per hour of travel by using a non-minimum path should be avoided. Where alternate routes are not equal in length, adjustments will be made in modelling or the penalty reflected in the optimising objective function.

Optimisation will not necessarily be limited to one objective function. Overall speed may be maximised, overall delay minimised, or individual delay minimised. Some objective functions may be impractical due to the number of variables involved or the difficulty in accurately quantifying cost or pay-off constants.

Constraint equations will consist of the capacity of each of the routes and the total demand for each time interval. In other words, the available routes may not be used beyond their capacity, but all of the demand must be assigned to a route. Each route has a speed distribution assigned to it for various volume levels to represent the efficiency with which that route operates under varying conditions.

The constraint equations also simplify the system. The assumption is made that capacity is not exceeded on any route, and the constraints equations are made to reflect this. In the real world, capacity may often be exceeded resulting in vehicular queues. At the same time, all the demand on the defined system is assigned to a route. This is a relatively good assumption.

Linear programming can provide optimal allocation of demand represented by historical behaviour. Solutions can be found for a range of situations. When current conditions sufficiently match historical situations for which linear programming has provided a solution, the appropriate strategy best handling that situation can be applied to the current situation. This application should require simply the use of a two dimensional graph. Regions of a two dimensional graph will mark sets of conditions which can best be handled by a single strategy. A strategy will typically consist of one or more messages consisting of particular content and phraseology.

Nonlinear programming should be investigated regarding its applicability in solving congestion and optimising flow on the system. In non linear programming the speed-volume relationship will be represented by a non linear mathematical formula as it has been hypothesised to be.

Dynamic programming should be evaluated as a method to optimise the vehicle-kilometres-of-travel per time interval or total travel on the defined system. Complex relationships between speed and volume on the routes in the system can be more adequately represented by this method. Optimisation is more rigorous. Dynamic programming requires a great deal of effort and must be justified by superior results. A typical model for dynamic programming will be suggested.

Stochastic models may be formulated and applied if found to be appropriate and worthwhile. The probabilistic characteristics of traffic demand and system operations can be reflected in great detail in this type of model and optimisation approach.

EXPECTED BENEFITS

Information distribution along recreational routes during the peak travel season can make a significant contribution to optimising public thoroughfares and person-travel time. The effectiveness of such programs needs to be tested and evaluated at a location where it is badly needed.

Many remote recreational facilities around the advanced countries are typified by access routes with capacity insufficient for peak recreational volumes. Ski resorts, beach resorts, and parks are typically connected by routes that experience periodic congestion. Traffic congestion may occur regularly or irregularly but it is always disruptive to both the local population and the recreational traveller regardless of how it occurs.

One of the landmark attempts to deal with the special event or recreational-related traffic problems was the diversion scheme employed by the French at Grenoble in 1968. Police regulated traffic entering each of two alternate routes to the Olympic games. This effort was a clear recognition of the importance of minimising the loss of the travellers recreational time to traffic congestion. Recreation often involves being present at a specific location and time for a special event to which the traveller has committed considerable resources. Travel delay may cause him/her to miss the event entirely.

The use of various media, such as highway advisory radio, portable variable-message signs, and commercial radio should be evaluated. Their potential for disseminating motorist information can be judged by engineers in similar problem situations in other geographic areas. The most promising and productive media and methodologies should be given priority in implementation.

EXAMPLE OF BASIC RELATIONSHIPS

The basic concern is with traffic entering the system at point e in Figure 1 staying in the system on one of the routes, and finally leaving the system at point o. It is possible to leave or enter the system at many points along either of the routes. Therefore, any statement concerning the volume at one point related to the volume at another point is probabilistic to some extent. The volume entering at point e may leave the system before entering route A, B, or C. The relationships among volumes is given by the typical formula,

$$\sum_{jj=to}^{to+T} TVESE(j\,j) = Ao + Bo \sum_{jk=to}^{to+T} Vra\,(jk) + Co \sum_{jl=to}^{to+T} Vra\,(jl) \qquad (1)$$

where Ao, Bo and Co are least-squares regression constants, 'to' is the beginning of the study period, and T is the number of time intervals in the study[1].

The volume of vehicles electing to use route 'A' will depend to some extent on the advisory message given to the motorists and the length of time it is given. This relationship may be represented by the formula,

$$Vra\,(to) = (A_5 + B_5\,AMTC + C_5\,AML)\,(TVESE\,(to)) \qquad (2)$$

where AMTC is the stated traffic condition, and AML is the length of time the message is given[2]. Similarly, the volume at points on different routes will have a relationship that can be determined in a similar fashion. A typical relationship determined by lag cross correlation is given by the formula,

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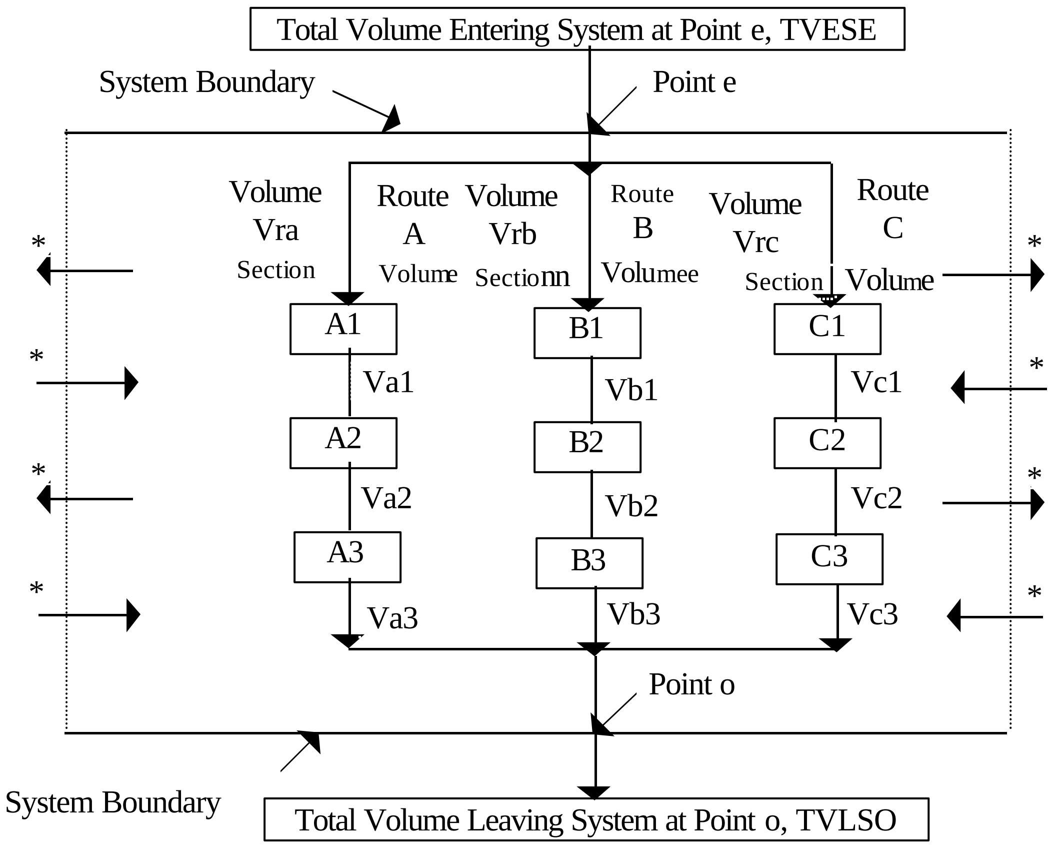
[1] See legend, Figure 1 for other variable notation
[2] Ibid

$$Vrb3\ (ts) = A_2 + B_2\ \ Vral\ (ts\text{-}tcl) \qquad (3)$$

where A_2 and B_2 are regression constants, vrb3 is the volume on section B_3 at time ts, and tcl is the number of time intervals separating the strongest association between the mangnitude of the volume on section B3 and that on section A1.



* Vehicle may enter or leave system at any point

Legend

TVESE(to)	Total Volume Entering System at Point e for Time Interval (to)
Vra(to)	volume entering route A from point e for (to)
Va1	volume leaving section A1 for time interval (to)
Va2(to)	volume leaving section A2 for (to)
TVLSO(to)	Total Volume Leaving System at Point o for (to)

Figure 1: System Definition

Volume on a route at a point is influenced by the volume on the same route at an upstream point for an earlier time interval. Vehicles may enter and exit at any point, but many vehicles are travelling through the entire system from point e to point o in the system shown in Figure 1. The relationship determined by lag autocorrelation is given by the typical formula,

$$Vra3\ (ts) = A_1 + B_1\ Vral\ (ts - tl) \qquad (4)$$

where A1 and B1 are least squares regression constants, as is a designated time interval, vra3 is the volume leaving section A3, vral is the volume leaving section A1, and tl is the time intervals separating a strong correlation between flow at the end of sections A1 and A3.

EXAMPLE APPLICATION OF LINEAR PROGRAMMING

The application of linear programming is depicted with several mathematical formulae.
The objective function or measure of effectiveness is given by the formula,

$$tvm = (sca)\ (Va1 + Va2 + Va3) + (scb)\ (Vb1 + Vb2 + Vb3) + (scc)\ (Vc1 + Vc2 + Vc3) \qquad (5)$$

where sca is the speed of operation of route A, scb is the operating speed for route, B, va1 is the volume on section A1, and va2 is the volume on section A2.

One set of constraints is that the capacity of any route may not be exceeded. This set is given in the following formula,

$$\begin{aligned} (Va1 + Va2 + Va3) &\leq Ca \\ (Vb1 + Vb2 + Vb3) &\leq Cb \\ (Vc1 + Vc2 + Vc3) &\leq Cc \end{aligned} \qquad (6)$$

where Ca is the capacity of route A, and Cb is the capacity of route B.

The final set of contraints is that all of the demand for any time interval must be assigned to one of the routes. This set is given in the following formula:

$$\begin{aligned} &Va1 + Vb1 + Vc1 \quad D1 \\ &Va2 + Vb2 + Vc2 \quad D2 \\ &Va3 + Vb3 + Vc3 \quad D3 \end{aligned}$$

where D1 is the demand for time interval 1.

SUMMARY AND CONCLUSIONS

There is an obvious need to reduce congestion in metropolitan areas. However, knowledge of what portions of the total traffic should be assigned to the various routes to optimise the overall operation will be gained. By knowing what the usage is and what the usage should be to gain an optimal operation leads to estimates of delay and expected travel time.

Furthermore, recreational routes frequently involve many jurisdictions that cannot provide a coordinated program for traffic control and information gathering. Consequently, a methodology is needed to solve special traffic problems of the type occurring on the Sydney North Sydney Corridor. An analysis plan, solution implementation and evaluation methodology would benefit the problem at hand as well as traffic engineers in jurisdictions that have similar problems.

This conceptual model (system definition) offer a number of benefits to the heavily travelled recreational road network corridor. The characteristics of the problem and potential solutions should be defined, tested, evaluated and documented.

In conclusion, traffic planning for a periodic peak traffic is very important to the recreation-oriented motorist. Leisure hours are intended for leisure not for sitting in traffic delays. Delays to the traveller headed for the beach are weighted more heavily. This phenomena should be studied and used to provide perspective on the benefits of traffic management for the heavily recreational road network.

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