A QUEUEING BASED TRAFFIC FLOW MODEL

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INTRODUCTION

Due to increased ownership of cars, changes in the production system (where stock is on the road and not in the warehouse), increased flexibility of the working population, etc., the demand for transport has increased exponentially. This combination of more and more traffic on the existing road network together with a stabilization in investments of new roads, results in an inevitable increase of congestion. Congestion leads to an increase in travel time, decreasing flow, higher fuel consumption, negative environmental effects, etc.

Using queueing models we can model the above situation, and traffic conditions can be improved. Traffic will be modelled using mathematical models based on queueing theory. This analytical basis, rather than an empirical one, has the advantage to adequately pinpoint possible problems and to perform sensitivity analysis, what-if questions, etc. Once traffic is analytically analyzed and modelled, the second step tries to adequately improve the traffic conditions, using these mathematical models.

QUEUEING APPROACH

In a queueing approach to traffic flow analysis, roads are subdivided into segments, with length equal to the minimal space needed by one vehicle on that road (Figure). Define C as the maximum average traffic density (i.e. average maximum number of cars on a road segment). This length is then equal to 1/C and matches the minimal space needed by one vehicle on that road. Each road segment is then considered as a service station, in which vehicles arrive at a certain rate λ and get served at another rate μ.

Plotting the traffic flow, density and (relative and effective) speed on a graph gives us the wellknown speed-flow-density diagrams. The exact shape of these diagrams depends upon the queueing model and the characteristics of the arrival and service processes.

Vandaele, Van Woensel and Verbruggen developed different queueing models for

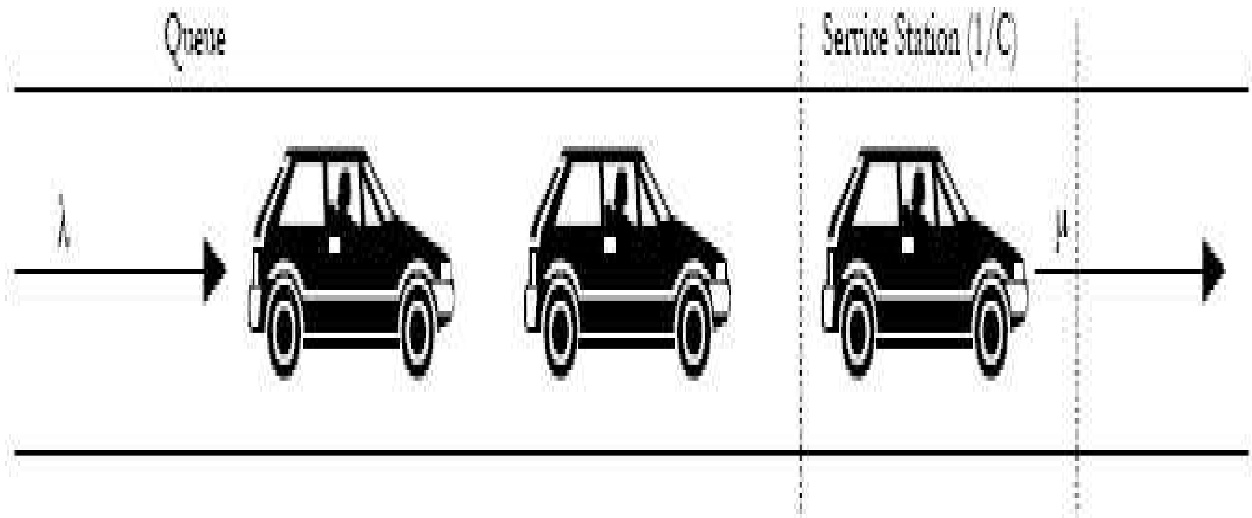

Figure 1: Queueing representation of traffic flows

single nodes. The $M/M/1$ queueing model (exponential arrival and service rates) is considered as a base case, but due to its specific assumptions regarding the arrival and service processes, it is not useful to describe real-life situations. Relaxing the specifications for the service process, leads to the $M/G/1$ queueing model (generally distributed service rates). Then $G/M/1$ queueing model (generally distributed arrival rates) is considered.

They made use of the known quantities like, Time in the system Effective speed (km/h) , Relative speed to consider the rates, λ and μ. For Example, consider the $M/M/1$ queueing model. Expected inter-arrival time is equal to $\frac{1}{\lambda}$, with λ equal to the product of the traffic density and the nominal speed. When a vehicle drives at nominal speed SN (say) , service time can be written as $\frac{1}{\mu}$, where μ is the product of SN and C.

Using the values of λ and μ, required quantities for the analysis like, traffic intensity, effective speed, traffic density etc. are computed. Then with the help of speed-flow-density diagrams analysis has been done, w.r.to all the above mentioned models.

CONCLUSIONS

Based on queueing theory we analytically constructed the well-known speed-flow-density diagrams. Using several queueing models, speed is determined, based on different arrival and service processes. The exact shape of the different speed-flow-density diagrams is largely determined by the model parameters. Therefore we believe that a good choice of parameters can help to adequately describe reality. We illustrated this with an example, using the most general models (including a state dependent model) for a highway. Due to the fact that speeds have a significant influence on vehicle emissions, our models can be effectively used to assess the environmental impact of road traffic.

In this paper, the existing single node models are extended towards queueing networks. The analysis can be split up into two parts: infinite and finite buffer sizes. Here, we discuss the infinite buffer size case. Road networks can then be represented by queueing systems. This approach results in speeds and densities at every node in the network and allows for sensitivity analysis, evaluation of policy actions,

References

[1] **Nico Vandaele, Tom Van Woensel and Aviel Verbruggen**, a queueing based traffic flow model, *Transportation Research-D: Transport and environment*, January 2000, vol. 5 nr. 2, pp. 121-135.