Models of vehicular traffic: An engineering perspective

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Abstract

The aim of the paper is to present an engineer's viewpoint of traffic streams and their models both at the macroscopic and microscopic levels. The paper concentrates on two classes of macroscopic models (namely, stream description models and travel time estimation models). At the microscopic level the paper concentrates on car-following models and also presents a relatively recent idea on developing a comprehensive microscopic model of driver behaviour. Finally, the paper presents some properties which all microscopic models of traffic flow should possess and also tries to identify areas where research will bring about a qualitative jump in the understanding of how traffic flows.

Keywords: Traffic flow models; Microscopic models; Macroscopic models

1. Introduction

The aim of this paper is to look at traffic flow models from an engineering perspective. The paper highlights the practical requirements from models of traffic flow. Specifically, four types of traffic flow models are covered. These are: (i) stream description models, (ii) travel time prediction models, (iii) longitudinal vehicle control models, and (iv) longitudinal and lateral vehicle control models. The first two are macroscopic models of traffic flow in that they refer to stream characteristics rather than individual vehicle motion; the last two are microscopic models of traffic flow as they describe individual vehicle motion in different driving scenarios. The microscopic models, at least in theory, can be used to study macroscopic properties of traffic streams.

This paper is not to be treated as a review paper of the various macroscopic and microscopic models developed in traffic flow. Rather, the aim of the paper is to give the reader an idea of the models in traffic flow theory from an engineering perspective. The way the paper is developed is as follows: first it attempts to describe the traffic stream from an engineers viewpoint both macroscopically and microscopically. Next the paper discusses how well the models describing the streams fare when compared to the engineer’s view of a traffic stream.

2. Macroscopic models

Macroscopic models of traffic flow attempts to describe the flow through certain macroscopic parameters and their inter-relationships. Typically the parameters used are speed, volume (or flow), and density.
(or occupancy); however in the case of interrupted flow (like on two lane, two-way roads or signalized intersections), often parameters like delay, percentage of time spent behind slow moving vehicles, etc. are also used in describing flow. The entire gamut of situations where flow needs to be studied separately is large. Here, a few of these areas are mentioned and later two situations are selected for further elaboration.

Flow characteristics in the following traffic facilities are reasonably different and are studied separately: (i) basic freeway segments—flow here is largely uninterrupted, (ii) two-lane two-way roads—flow here is generally uninterrupted but one can get “caught” behind slow moving vehicles for extended periods of times; overtakings by moving into opposing lanes are often necessitated in this case (iii) weaving sections—flow here is characterized by intense lane changing behaviour between merging and diverging traffic at reasonably high speeds, (iv) unsignalized intersections—here opposing traffic use a common road space and are controlled by static features like signs and channels, (v) signalized intersections—here opposing vehicles use the same area of the road on a time sharing basis, and (vi) arterial sections—here vehicles travel for reasonably long distances but are intermittently stopped by signalized intersections; these are typically seen in urban settings. In the following, the two areas described in greater detail are: (i) stream description models—these are applicable whenever vehicles travel on multilane roads with little or no interruptions and (ii) travel time models for urban arterials.

2.1. Stream description models

Classically, three variables have been used to describe a traffic stream: speed $u$, flow $q$, and density $k$. The relationships used in describing the stream are: (i) the fundamental relation, $q = uk$ [1], and (ii) models of $u$–$k$ relationships. Although, other pair-wise relations (like $u$–$q$, $q$–$k$ relations) are often reported and studied, it is felt that $u$–$k$ relations are the most fundamental as they are a direct outcome of the driving process (note that it is difficult to imagine that individual drivers have any notion of $q$ while driving).

Brief discussions on the following are provided: (i) $u$–$k$ and other relations, (ii) the fundamental relation and the use of density, and (iii) capacity determinations.

2.1.1. $u$–$k$ and other relations

Over the years various models have been suggested to capture pair-wise relations between stream variables; most of these are on $u$–$k$ relations. In the thirties, Greenshields [2] proposed a linear relation; later Greenberg [3] proposed a logarithmic relation based on fluid flow analogies of traffic stream movement. One of the most general descriptions of the $u$–$k$ relation is the generalized polynomial model derived from microscopic models of driver behaviour (see May [4] for more details). This model is

$$u^{1-m} = u_f^{1-m} \left[1 - \frac{k}{k_j} \right]^{l-1},$$

(1)

where $u_f$ and $k_j$ are free flow speed and jam density, respectively.

Many researchers have raised objections to the use of a single function to describe the $u$–$k$ relation over the entire density range (the so-called single-regime models) on the grounds that humans do not behave according to the same rules over the entire range of density values. There is some merit to these objections. Many multi-regime models were proposed with Edie’s [5] model being one of the first. Yet other researchers argued that it is better to look at the relationship among all the three parameters at once. The three dimensional catastrophe theory-based models (e.g., see Navin [6] and Persaud and Hall [7]) are an example of such an exercise.

2.1.2. The fundamental relation and the use of density

Obviously given the fundamental relation and the relation between $u$ and $k$ it is easy to see that pair-wise relations between all the three variables are possible. Often researchers collect data on speed and flow but represent the data as speed versus density; where density is obtained as the quotient of flow divided by speed. Many researchers have voiced concerns about using the $k = q/u$ to obtain density and then using that value of density for further investigations [8,9]. Further, even though, the relation may be valid under certain
“average” conditions or when space and time measurement approaches zero, its use to calculate density from point measures of speed and flow may result in incorrect estimates of density. Similar concerns have also been voiced by Hall [10].

Another way of estimating density is by converting occupancy (which is temporal concentration) to spatial concentration (density). Any introductory book on traffic engineering (for example, May [4]) will give the procedure. As pointed out by Hall [10] and Hall and Persaud [11] this also makes assumptions which may not be true under different flow conditions. The opinion generally is that, even though, under uncongested conditions conversion from occupancy to density may be acceptable, “once congestion sets in, there is probably no good way to estimate density; it would have to be measured” [10].

2.1.3. Estimating capacity

One of the pressing and important issues that an engineer has to understand is the capacity (the maximum value of flow, \(q_{\text{max}}\)) of a road and the related topic of quality of service a given facility provides to its users under different demand conditions. For this purpose, various codes of practice exist. These codes of practice use a more or less similar understanding of the speed–flow relation. One such diagram (see Fig. 1) is reproduced here from the 1998 American Highway Capacity Manual [12]. These diagrams generally do not expound on the flow conditions for densities beyond the optimum density value (the density at which \(q = q_{\text{max}}\)). As can be seen from the diagram there are different lines (hence, different stream behaviours) for different free-flow speeds. The issue in front of an engineer is to figure out which is the appropriate line for a given set of road conditions. Alternatively, an engineer has to answer questions like what is the best road design (or combination of road features like, number of lanes, lane width, lateral clearance, etc.) if one requires it to have a certain capacity or needs it to provide a certain quality of service.

The problem is that of having models which relate the road features to the expected speed–density or speed–flow behaviour. At present there are no such models (more will be discussed on the topic in the section on microscopic models). Most codes of practice follow empirically based ad hoc procedures to come up with capacity values for a given set of road conditions. For example, the 1998 Highway Capacity Manual [12] provides tables of values which give the amount by which free speed should be reduced from its expected value (on ideal roads) for non-ideal conditions. Then this obtained value of free speed for a given set of conditions is to be used to determine the most appropriate \(u-q\) relation from the figures like the one reproduced here as

![Fig. 1. The \(u-q\) relations in the 1998 Highway Capacity Manual [12] and their dependence on free flow speed (which in turn depends on the physical features of the road).](image-url)
Fig. 1. For determination of quality of service similar empirical procedures are generally provided. The interested reader may refer to the various codes of practice to realize the extent of reliance on ad hoc procedures.

It must be pointed out here, at the cost of being repetitive, that a lot of research is going on in trying to replicate the observed macroscopic relations from simple driving rules; however, little or no research is currently on to relate roadway features and traffic features (like vehicle mix, driver mix, etc.) to the flow behaviour. Hence, reliance of traffic engineers on ad hoc and empirical relations continues. Despite advances in computation abilities and theoretical insight this reliance has not changed in the last half-a-century. Surely, this needs to change and the author feels researchers must now channelize their energy to evolve models which will reduce such reliance.

2.2. Travel-time models

Another area of large practical significance is that of predicting travel time on roads. The problem assumes even more significance for urban arterials which typically have many flow interruptions in the form of intersections, parking maneuvers, pedestrian crossings, etc. These disruptions hardly allow the flow to settle down to “situations” where steady-state assumptions may hold.

Over the years various forms which relate travel time to a variety of factors such as distance from central business district (for example, see Branston [13]), flow on roads and signal timings (for example, see Wardrop [14]), flow of two fluids—stopped vehicles and moving vehicles, being the two fluids—(e.g., see Herman and Prigogine, [15]) have been proposed. Although, these models have all served a purpose in understanding the system better, the present day needs cannot be served by them.

Today, the need for travel-time estimates are required as a part of the advanced traveler information system (ATIS). ATIS can play an important role in efficient utilization of existing resources through more effective demand distribution. As the name suggests, the success of ATIS depends on how effectively one can obtain reliable and reasonably accurate information on parameters like travel time (on road sections) and disseminate the information to prospective users of the road sections. Further, the estimates need not be long term, like “on an average at a flow value of $q$ travel time will be $t$” rather the estimates should be of the form “if you get on the road in the next 10 minutes your travel time will be $t$.” As can be seen, analysis which assume steady-state behaviour of traffic flow cannot be used for such short term but reasonably accurate estimates.

A lot of work is currently going on in the area of travel-time predictions in the short term with reasonable accuracy. The models typically rely on stream sampling through static devices such as presence type detectors or through moving vehicles referred to as probes (for example, see Refs. [16,17]). However, these models rely primarily on some type of correlation analysis; further, there are many sampling issues which still remain unresolved or partially resolved. It is felt that a large scope exists for the development of theoretical models which can give better (unbiased and efficient) estimates of the population travel time on road sections with minimal sampling.

3. Microscopic models

As opposed to the macroscopic models, microscopic models attempt to define the behaviour of a traffic stream by describing the behaviour of individual drivers in different driving situations. In general, drivers have two basic tasks, (i) controlling the vehicle’s position along the direction of motion, and (ii) controlling the vehicle’s position along the width of the road or lane. The first task is referred to as longitudinal control and is achieved by controlling the vehicle’s speed (i.e., through acceleration/deceleration). The second task of lateral control is achieved through proper choice of steering angles. In reality both these activities are inter-dependent and goes on concurrently.

However, in order to simplify the understanding of driving behaviour, often it is assumed that the primary task of a driver is the longitudinal control of the vehicle. This assumption is largely true where the road characteristics are reasonably same for long distances, vehicles have well demarcated travel paths (like lanes) and vehicles do not generally cross these demarcations; even when they do, it is a discrete
event (like lane changing). Under these assumptions, the vehicle is assumed to be only under the influence of vehicles traveling in the same path (or lane); that is, only longitudinal interactions are taken into account.

When lane discipline is not maintained or in situations of extensive weaving (merging or diverging of traffic streams like at roundabouts or near on-or-off ramps) there is considerable lateral interactions between vehicles. In such cases studying the process of longitudinal control of vehicles will not suffice; one has to look at the process of longitudinal and lateral control of vehicles in a comprehensive manner. In fact, models which can account for both lateral and longitudinal interactions between vehicles can in general be used to study the interactions of vehicles with other features of the road like road edges, geometry, static obstacles like parked vehicles, etc. It is felt that such models will provide a basis for relating capacity of roads (or more generally flow behaviour) to engineering features of the road like width, radii of curves, lateral clearance, and the like. Hence, the ultimate goal of modeling traffic flow must be to evolve a model of driver behaviour which can handle both longitudinal and lateral interactions and is simple enough to be used to simulate a large number of vehicles at a time so that macroscopic properties of the road can be studied. In the following, some of the properties of (i) longitudinal control behaviour and (ii) longitudinal and lateral control behaviour of drivers and their models are described.

3.1. Longitudinal control behaviour and its models

The driver’s behaviour in situations where the driver primarily performs longitudinal control can be broadly divided into three regimes: (i) free-flow behaviour, (ii) car-following behaviour, and (iii) stop-and-go behaviour.

In free-flow behaviour the driver is not encumbered by other drivers. The driver can choose his speed and maintain it purely at his will. No models, except ones which can determine the choice of speeds (or free speeds) of vehicles given the road conditions are necessary. As mentioned earlier that is not within the purview of longitudinal control models, rather such choice of speeds are affected by the lateral impact of roads edges and other such static obstacles on the driver’s mind. Further, free-flow behaviour occurs when density is very low and the average distance headway between vehicles is much larger than what can be reasonably assumed to be a value at which leading vehicles (LVs) can hinder the following vehicle’s (FV’s) motion.

As densities increase vehicles start traveling closer to one another. In such situations the actions of a vehicle are affected by the state (or actions) of the LV. Speeds of vehicles fall below their desired speed. In such situations there is constant tug-of-war between two conflicting motivators—the need to reach the destination as quickly as possible (i.e., urgency) and the concern for one’s safety. Further, it is human nature to feel threatened if distance headway is small at high speeds; hence as distances reduce so does speed (this can be seen on a macroscopic scale from any data on $u$ and $k$). So what happens is that the following vehicle constantly tries to increase the speed (effect of urgency) but in so doing closes in; this increases the threat to safety and the person reduces the speed. This behaviour is referred to as car-following behaviour. This is the prevalent form of driving, meaning this is the mode in which drivers are for the largest range of densities (may be from 8 to 10 vehicles/km/lane to about 60 vehicles/km/lane). In the latter parts of this section more is discussed about this important driving behaviour. One may also refer to Chakroborty and Kikuchi [18] for a better exposition.

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At the other end of the density scale, where densities are large, vehicles move with frequent halts or near halts. This kind of traffic is referred to as stop-and-go traffic. Driver behaviour in this region is impacted by the vehicles ahead. However, the strength of the relationship is not as strong as in the car-following case; often it is seen that vehicles keep longer than safe distances, vehicles do not immediately respond to spacing increments; etc. It seems that the primary motivator in these cases is only safety and urgency plays a lesser role. Similar observations have been made by others (for example, see Minderhoud and Zurbier [19]). It is felt, that very little empirical research has been reported on stop-and-go traffic and more needs to be done to understand the behaviour better.

In the rest of the section, the discussion is on car-following behaviour as it occurs in streams with low to reasonably large densities and is possibly the most difficult-to-model aspect of the driving regimes.
3.1.1. Properties of car following

In the following the important properties of car-following behaviour are enumerated. Some of these properties are applicable to all driving scenarios.

**Property I.** Car-following is a stimulus response process. Like with all such processes there is a time lag between the stimulus and the response. This is the perception–reaction time. Observations suggest that it can be anywhere between 0.75 to 1.5 s. Further, since this is a control process, it is important that a model of car following (or driving in general) explicitly incorporates this time lag. Any model that does not explicitly account for this lag cannot be considered a model of driver behaviour. This time lag should not be confused with the update time used in many simulation models. Fig. 2 shows some examples of car-following behaviour collected by the author in the early nineties on the roads of Delaware, USA. As can be seen from the figures there is a close relation between the speed variations of the leading vehicle (LV) and the following vehicle (FV) indicative of the car-following behaviour; further, the line representing the speed variation of the FV seems similar to the line showing the variation of the speed for FV but shifted laterally along the time axis; this lateral shift is indicative of the perception–reaction time.

It is generally agreed that the factors that affect actions of the FV (in the case of car-following behaviour actions are in terms of accelerations) are distance headway (the distance between LV and FV), relative speed (rate of change of distance headway), and acceleration or relative acceleration (rate of change of relative speed); for example, see Gazis et al. [20], Rothery [21], Kikuchi and Chakroborty [22]. Although, there have been some reservations about whether accelerations can be perceived, modern research seems to suggest that it can be [23]. Further, it may be pointed out that relative speed and relative accelerations give the driver of the following vehicle an idea of the state of the system in the near future; that is, it gives the driver a power to anticipate.

**Property II.** Car-following is a human process. Humans have limits on what they can and cannot perceive—there are perceptual thresholds; for example, see Evans and Rothery [24,25] or Leutzbach [26]. Hence models on car-following should not assume that the driver can perceive minute changes in say, relative speed or distance. Nor should models assume that drivers can react exactly according to some precise rule; there will always be variations. That is, car following in reality is an approximate process as are all human decision making and response processes [27–29].

**Property III.** Car-following is an asymmetric process. That is, drivers react differently when distance headways reduce than when distance headways increase. For example, Leutzbach [26] suggests that this asymmetry is due to the fact that “drivers pay closer attention to decreases in spacing than to increases in spacing simply on the basis of their own safety.” Herman and Rothery [30] also observed this asymmetry.

**Property IV.** Car-following behaviour is stable. Fig. 3 shows a real world situation where the LV–FV pair is stable (from around 20 to 40 s)—the distance headway remains at an approximately constant value. Stable conditions are those where the driver of the FV does not feel the need to either accelerate or decelerate. This condition is characterized by relative speed (between LV and FV) of zero and distance headway equal to safe conditions.

![Fig. 2. Examples of car-following behaviour (from Chakroborty and Kikuchi [18]).](image-url)
distance headway (SDH). For a given road geometry, the value of SDH depends on speed of the FV and nothing else. The fact that SDH is higher at higher speeds can be easily seen from the $u$–$k$ relationships.

There are two types of stability which are exhibited by vehicles in traffic streams. These are schematically presented in Fig. 4. The first type of stability is referred to as local stability. In an LV–FV pair if the LV settles down to a constant speed after initial perturbations, then the speed of the FV will also settle down after some time to the same value as that of the LV (i.e., relative speed is zero); the distance headway at which the vehicles finally settle down will be equal to SDH. This property is referred to as local stability and can be clearly seen in Fig. 3. One may say the temporal damping of the perturbations to distance headway between an LV–FV pair

![Fig. 3. Car-following behaviour showing local stability (source: Chakroborty and Kikuchi [18]).](image)

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<tr>
<th>Situation</th>
<th>Concept of local stability</th>
<th>Concept of asymptotic stability</th>
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<td>LV &amp; FV</td>
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<td>Speed vs. time plot</td>
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<td>Distance headway vs. time plot</td>
<td><img src="image" alt="LV &amp; FV schematic" /></td>
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![Fig. 4. Schematic explaining the properties of local and asymptotic stability.](image)
is local stability. It is also understood that in a long platoon of vehicles, if the leader introduces a perturbation then that perturbation dies out as it travels upstream in the platoon. That is, the spatial damping of perturbation to distance headway is referred to as asymptotic stability. This behaviour is expected, since its non-existence implies that a minute perturbation will always cause an accident in a sufficiently long platoon—which is never the case. One may refer to any book on traffic-flow theory for a detailed description of these properties (e.g., see May [4]).

**Property V.** Car-following behaviour exhibits properties of closing in and shying away. Even if the LV moves at a constant speed, the FV may choose to accelerate (or maintain a negative relative speed for a reasonably long time) if the distance headway is larger than SDH (for the speed at which the LV is traveling). This is closing-in behaviour. A re-look at Fig. 3 shows that from around 5 to 15 s the FV maintains a negative relative speed (this is much longer than one would observe if the distance headway was smaller) so as to reduce the distance headway (or close-in). If on the other hand the distance headway is smaller than SDH then the FV may choose to decelerate (or maintain a positive relative speed) so as to increase the distance headway to SDH; this is shying away behaviour.

### 3.1.2. Models of car following

Over the years various models of car following have been proposed. An overview of the models can be found in Brackstone and McDonald [31]; although this author does not agree with all of its conclusions. Here two of these models are mentioned. Note that, as stated earlier, this paper is not a review paper; and hence the choice of models here are based purely on the idea of whether they illustrate an engineer’s perspective of how these models should be. The models described here are the GHR models (one of the first set of models in this area) and the fuzzy rule-based models (one of the most recent developments in this area).

The GHR models [20,32–35]) proposed the following stimulus–response car-following rule:

\[
\dot{x}_{FV}(t + \delta t) = \alpha_{L,m} \frac{(x_{FV}(t + \delta t))^m}{(x_{LV}(t) - x_{FV}(t))} \left( \dot{x}_{LV}(t) - \dot{x}_{FV}(t) \right).
\]  

(2)

This rule with a proper choice of the exponents yields actions which give rise to stability. However, its reliance on only relative speed as the stimulus (the other factors simply modify the response to the stimulus) gives rise to certain problems; for example, this model cannot replicate the closing-in and shying-away behaviour. Further, it can be shown that the SDH obtained using this model is sensitive to initial conditions and perturbation pattern [18], which it should not be. These errors not withstanding, what this model showed for the first time was that expressions on the FV’s actions could be derived which gave rise to stable behaviour. The author believes that stability is an important car-following property which every microscopic model of traffic flow must exhibit.

The fuzzy-rule-based model was initially proposed by Kikuchi and Chakroborty [22]. These models form the “latest distinct stage in their (car-following model’s) development, as it represents the next logical stage in attempting to accurately describe driver behaviour” [31]. Others have since then worked in this area. The fuzzy rule based model [18,22,36] simply models driver behaviour by specifying a set of linguistic rules on what to do under different circumstances. For example, a rule could be:

IF (at time \(t\)) the Distance headway is very large AND Relative speed moderately negative AND Acceleration of LV is negative THEN (at time \(t + \delta t\)) FV should accelerate mildly

The circumstances (or premise/antecedent) which are described linguistically are mathematically represented as fuzzy sets. For example, descriptors like very large, moderately negative, etc. are all described through fuzzy sets. The actions (or consequents) are also described approximately through fuzzy numbers. Under a given condition, many rules are activated and a compromise decision (based on the truth value of the antecedents) is taken. The results from the model show that all the properties of car-following behaviour are satisfied [18]. The author believes that this model illustrated that simple rules-of-thumb can explain in all details such complicated behaviour as car-following. In this sense, it is felt that rule-based structures like the
ones that can be employed in cellular automata models can be successful in realistically representing driver behaviour and hence the macroscopic behaviour of the traffic stream.

Before leaving this section it must be pointed out that all models which are in essence microscopic models of traffic flow (like the cellular automata-based models) must be subjected to tests which determine whether these models possess the properties mentioned earlier. Certain properties, like stability, independence of SDH from initial conditions and perturbations, and dependence of SDH on speed of FV are essential for any microscopic model. If these properties are absent, then the model’s predictions at a macroscopic level also become suspect.

3.2. Lateral and longitudinal control behaviour and its models

As stated earlier, the final goal in microscopic modeling is to be able to devise a comprehensive model of driver behaviour; a model which under one framework can explain a driver’s choice of steering angle, speed, and acceleration values under various different driving situations. That is, such models should be able to describe the path of every vehicle over space and time. Such models should be able to explain among other things, the responses of drivers in the following situations:

- **Free-flow conditions**: in such situations drivers are not affected by other vehicles; however, their actions are motivated by roadway features like lane width, lateral clearance, road geometry and other static features like parked vehicles, potholes, etc.
- **Car-following conditions**: these situations have already been described earlier.
- **Weaving conditions**: in such situations, there are extensive crossing of paths of vehicles within a short length; this kind of situations arise in roundabouts with merging and diverging traffic or when on-ramps and off-ramps are placed in close proximity.
- **Passing (or overtaking) conditions**: these are situations where a vehicle wishes to overtake a slow moving vehicle; these situations either lead to a change of lane (on multilane roads) or an intrusion into the opposing lane (on a two-lane two way road case). In either of these situations the driver must look into whether an opportunity to overtake is present (i.e., whether appropriate gaps exist in the “other” lane and ahead of the slow moving vehicle) and then decide on the appropriate actions for steering control and speed control.
- **Two-way flow situations**: in such cases vehicles are affected by oncoming vehicles; the impact becomes perceivable when the road is not wide and the demarcation between the two flows are not rigid (for example on residential or local roads without a median divider).

The only comprehensive models, to the best of knowledge, are those developed at IIT Kanpur (for e.g., see Gupta et al. [37] and Chakroborty et al. [38]). These are force field (or potential field)-based models. The force field idea was also used by Helbing and Tilch [39] to model traffic dynamics; but the study was limited to only longitudinal control and hence did not contribute towards the development of a comprehensive model as envisaged here.

The IITK models are based on the following simple ideas:

(i) every goal (or “local” destinations like “ahead of the previous vehicle”) emanates attractive (or negative) potentials and every other feature on the road (like road edges, parked vehicles, moving vehicles, etc.) are considered as obstacles which emanate repulsive (or positive) potentials,

(ii) the potential at a point on the road is assumed to be the algebraic sum of all the potentials from the various obstacles and goals,

(iii) the potential at a point is perceived as a threat to a driver’s safety; the threat increases with speed; hence, it is assumed that the sustainable speed (a speed at which a driver feels comfortable) at a point is inversely related to the potential at that point,

(iv) given that a driver wishes to reach his destination quickly, he chooses the path which minimizes the potential (and hence maximizes the speed).

Based on these simple ideas response models (which control the steering angle and acceleration of the vehicle) were developed and tested; the results are encouraging [38]. However, from an engineering perspective, there are some problems. The biggest is that the model is computation intensive. It is felt that the framework of cellular automata may be useful to reduce the computation involved in this model. For example,
one could use the idea of potentials to describe attractiveness of cells and then define vehicular response based on these attractivenesses. One may then use the model to simulate enough number of vehicles so as to study macroscopic properties of the stream. In conclusion it may be mentioned that a “potential field”-based structure seems to provide a way to model the longitudinal and lateral control behaviour of drivers and must be pursued further.

4. Conclusions

The objective of the paper is to point out some of the gaps in macroscopic and microscopic models of traffic flow. The paper highlights that more than obtaining ever more sophisticated models of $u-q-k$ relations what one requires are models which relate the physical features of roads to the stream characteristics on them. This will allow capacity and quality-of-service analyses (the corner stones of design of traffic facilities) to become less reliant on ad hoc relations and parameters. The paper also points out that with information playing an important role in the demand management on traffic facilities the need for short-term accurate information on traffic parameters like travel time have become important. Assumptions of “long-run behaviour” or “steady-state behaviour” are no longer tenable.

The paper further points out the requirements of microscopic models of traffic flow. It suggests some tests which any model claiming to be a microscopic model must be put through. Macroscopic predictions from “microscopic models” which do not satisfy the properties of such models cannot be relied upon irrespective of how “realistic” the macroscopic predictions might “look.” Finally the paper highlights a possible framework for developing a comprehensive microscopic model of traffic flow.

References