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IDENTIFICATION OF VEHICLE AND ROAD PARAMETERS TOWARDS TRAFFIC MODELLING IN NETWORK ENVIRONMENT

Mr Vase Jordanoska, Dr Darko Danev, Dr Aleksandar Kostikj

University "Ss. Cyril and Methodius" Faculty of Mechanical Engineering, Skopje, MKD

ABSTRACT

Traffic congestion is one of the biggest issuethatpeople are facing with. Increased traffic flow implies to increased pollution, which affects people’s health and the environment. In such conditions arises theneedfor planning and improving of traffic flows in urban areas, but also at motorways. Traffic modeling and simulation tools have significant role in achieving these goals. The inclusion of vehicle dynamics aspects in these tools is analyzed, because this research field is multidisciplinaryand includes aspects from different scientific areas. The findings show that there is a space for improving of traffic models by adding vehicle / road parameters which will result in more realistic presentation of vehicle behavior.

KEYWORDS: Traffic Flow, Vehicle Dynamics, Vehicle and Road Parameters, Model, Simulation

1. INTRODUCTION

Human safety and environment protection are main research purposes in many engineering areas. As the population in the world grows, the problem with traffic congestion and accidents also arises. The problem is especially evident in big cities, during the working hours. The problem approach first requires analysis of regular traffic flow capacities, and then planning and improvement of traffic flows.

Simulation of vehicle behavior and traffic is an indispensable instrument for engineers in planning and improving of traffic flow [1, 15]. Mechanical, electrical, traffic and information and communication engineers are working together in this multidisciplinary field. Many European and international projects and research institutions work on the development of intelligent transport systems to improve the traffic flows and increase the safety of the users.

More software packages for traffic simulation and analysis are developed. These tools set greater emphasis on traffic aspects, such as the interaction between vehicles. From the vehicle behavior viewpoint, not enough parameters are included which characterize vehicle dynamics. This reflects on the results obtained by such tools in terms of actual behavior of a vehicle, which is especially evident in certain driving situations and conditions.

The paper is organized as follows. Section 2 presents the structure of developed traffic simulation tools. Vehicle dynamic aspects are presented in section 3 and vehicle models used in traffic modeling in section 4. The analysis of vehicle and road parameters, which have influence on vehicle behavior, is given in section 5. Conclusions are drawn in section 6.

2. STATE-OF THE-ART IN TRAFFIC SIMULATIONS

Traffic simulation tools use networks approach as basis in traffic modeling, since it is proved to be suitable in many scientific fields. Road infrastructure has network representation [1, 10, 11, 13].Network is a set of two items.First ones are named nodes, and others which connect them are named links(figure 1) [14, 18]. Both items may be accompanied by certain properties. In mathematical literature these systems are called “graphs” and are part of discrete mathematics. Network application found its use in many areas of different sciences, to present connections or interactions between parts of a system.The networks can be directed, which means links run only in one direction, from start to end node. Visually it is presented as a link with arrow, given on figure 1. In undirected networks, links run in both directions.

According to [18] the use of theory of graphs in science has three goals. First one is to find statistical properties which characterize the structure and behavior of certain system and how to measure them. Second one is to create network model through which the properties will be understood, i.e. the way they interact mutually. The third goal is to forecast system behavior based on the measured structural properties and determined rules of interaction.

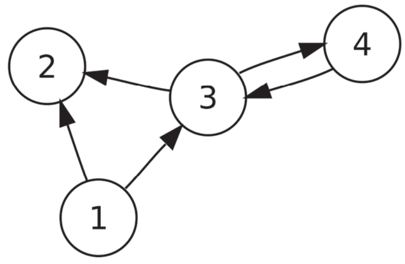


Figure 1. Directed graph

In road networks, intersections, dead ends, parts of roundabouts and sometimes points of streets are defined as nodes and road segments between them are links. These are directed networks because links show the direction of travel. Properties that are possessed by nodes and links in different traffic simulation tools are similar.Characteristics ofsome traffic simulation tools are given below in more detail.

VISSIM is a microscopic, behavior-based multi-purpose traffic simulation tool to analyze and optimize traffic flows. German: VerkehrInStädten – SIMulationsmodell, was originally developed at the University of Karlsruhe in early 1970s [12]. VISSIM offers a variety of urban and highway applications, integrating motorized transport, goods transport, rail and road related public transport, pedestrians and cyclists [13]. The software displays all road users and their interactions and it is used for evaluation and planning of urban and extra-urban transport infrastructure. In VISSIM the user creates the road network. Nodes and links are set through Network Editor with the help of background map. The direction of movement is defined by start and end node to which the link is dragged. Attributes which go with the link include:

- Designation of the link.
- Number of lanes.
- Length.
- Type of behavior (urban, freeway).
- Display Type (road, rail, pedestrian area, obstacle ...),
- Lane width.

SUMO (Simulation of Urban MObility) is an open source, microscopic and continuous road traffic simulation package, designed to handle large road networks [10, 11]. The simulation is multi-modal, which means that beside the vehicle movements, public transport systems are also modeled on the street network [10, 11]. SUMO is developed in collaboration between the Center for Applied Informatics Cologne (ZAIK) and the Institute of Transportation Systems (ITS), at the German Aerospace Center (DLR). Since 2004, the work on SUMO is continued at the DLR only, though with contribution from external organizations or individuals.

SUMO software is developed on C ++ base. The software consists of four sub-programs: NetEdit, OSM Web Wizard, SUMO Command Line and SumoGui. Road network is loaded or modified with NetEdit. Usually, network is loaded from OpenStreetMap, but may also be taken from other sources. Information which is carried by this type of network includes:

- for the nodes: node ID, X and Y coordinates, if it is a crossroad, if traffic light exist on a certain node and if the node presents mini roundabout;

- for the links: first and end node, description (street name), road type (motorway, major or other), maximum allowed velocity and the number of lanes.

There are also other tools for traffic simulation such as Paramics, Aimsun or MITSIMLab that are designed in a similar way as the described software [1].

3. VEHICLE DYNAMICS

Vehicle dynamics is acomplex areawhich has an important role in the development of vehicle industry. It studies vehicle behavior in different driving situations and conditions. At the beginning, around 1930s', researchers focused on the steering, suspension mechanics and driving stability, but lately accent is given on the vehicle ride comfort and handing stability [8].Vehicle dynamics has more aspects and can be studied as:

- Longitudinal,
- Lateral or
- Vertical vehicle behavior.

Longitudinal and lateral dynamics represent planar vehicle behavior, whereasvertical dynamics studies the vehicles' vertical oscillations which are caused by road imperfections. All these aspects affect the stability and handling of the vehicle. Figure 2 shows vehicle movements in a three dimensional coordinate system, along axes.

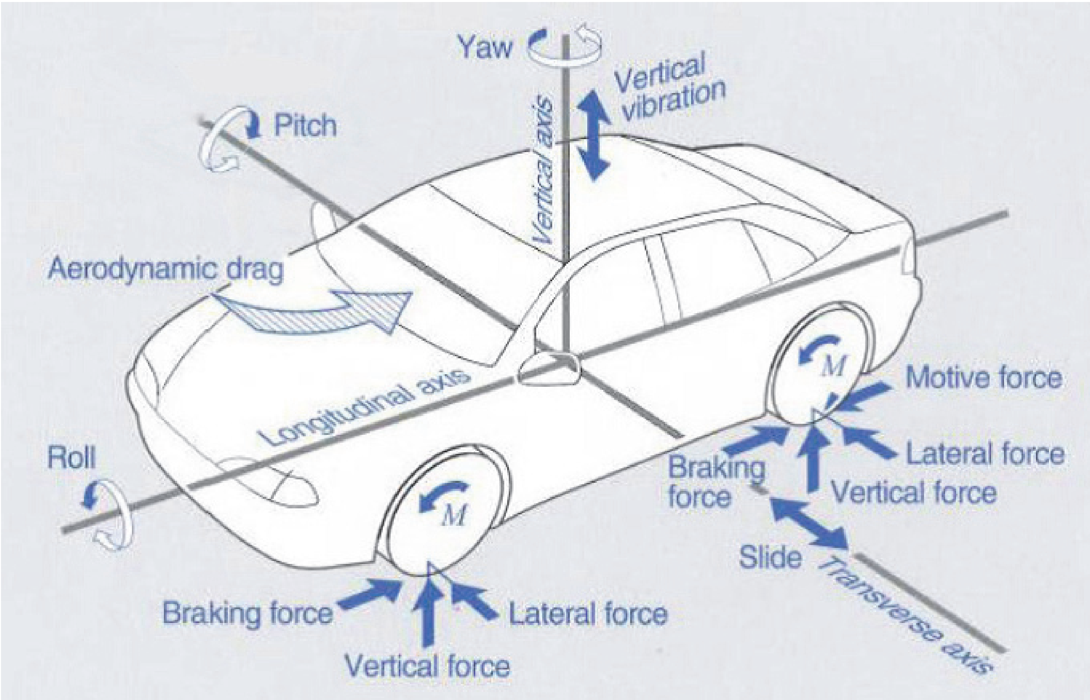


Figure 2.Coordinate system to describe vehicle movements

Longitudinal vehicle dynamicsis influenced by longitudinal tire forces, aerodynamic drag forces, rolling resistance and gravity, as well as by powertrain characteristics. According to the Figure 3, the equation of vehicle motion can be derived from the equation of force balance along the vehicle longitudinal axis:

$$X_M = R_a + R_\alpha + R_V + R_{fF} \tag{1}$$

i.e.

$$F_{ta} - G_M \cdot f = \left(\frac{G}{g} \cdot \frac{\sum J_F}{r_d^2} \right) \cdot \frac{dv}{dt} + G \cdot \sin\alpha + k \cdot A \cdot v^2 + G_F \cdot f \tag{2}$$

which leads to the differential equation of vehicle's motion:

$\frac{dv}{dt} = \frac{F_t - \sum R}{\frac{G}{g} \cdot \delta}$, where δ presents the influence of rotational masses of the vehicle. (3)

Lateral (transverse) dynamics refers to vehicle handling stability and presents the influence of the slip angle of the vehiclecaused by tire lateral force, yawing and roll motion and also slip angles of wheels. Generally, planar vehicle behavior is studied through "bicycle" model of a vehicle with two degrees of freedom[2, 3, 4, 8], given on figure 4.

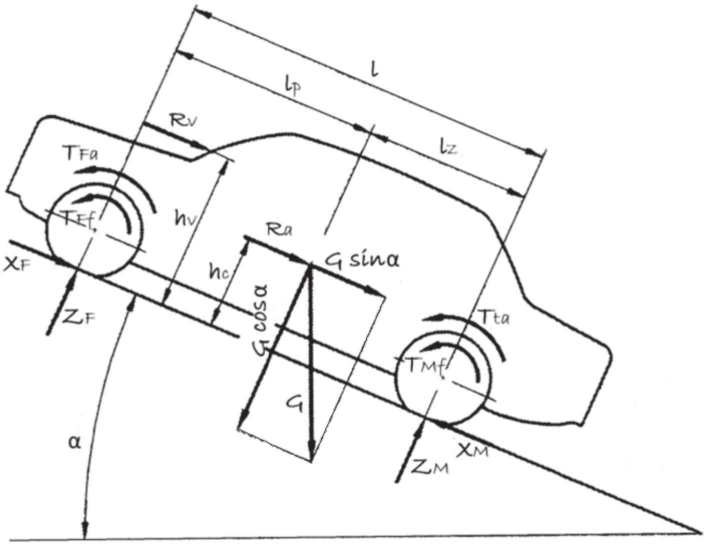


Figure 3. Longitudinal forces acting on a vehicle moving on an inclined road

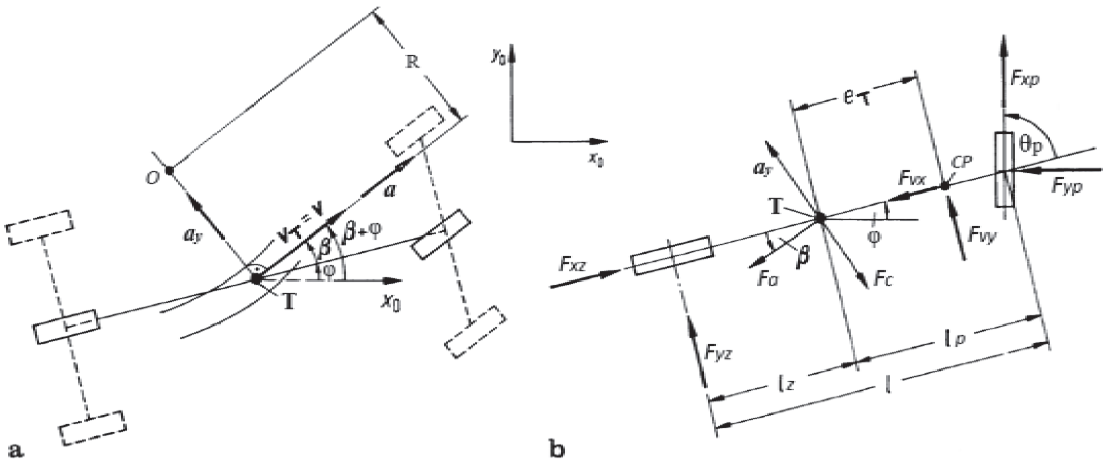


Figure 4. Kinematic scheme and forces on a “bicycle” model of vehicle

The state of a vehicle “bicycle” model is described through the equitation of balance of forces in longitudinal (4) and lateral (5) direction and the equation of the moment balance in the center of mass (6).

- Force balance in longitudinal direction

$$F_C \cdot \sin\beta - F_a \cdot \cos\beta + Fxz - F_{VX} + F_{XP} \cdot \cos\theta_p - F_{YP} \cdot \sin\theta_p = 0 \tag{4}$$

- Force balance in lateral direction

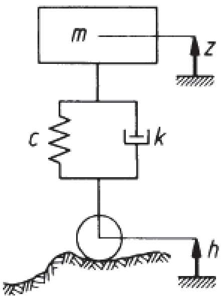
$$F_C \cdot \cos\beta + F_a \cdot \sin\beta - F_{YZ} - F_{VY} - F_{XP} \cdot \sin\theta_p - F_{YP} \cdot \cos\theta_p = 0 \tag{5}$$

- Moment balance in the center of mass T

$$I_Z \cdot \varepsilon - \left(F_{YP} \cdot \cos\theta_p + F_{XP} \cdot \sin\theta_p\right) \cdot l_P + F_{YZ} \cdot l_Z - F_{VY} \cdot e_T = 0 \tag{6}$$

These formulations lead to the differential equation of vehicle's planar motion.The longitudinal and lateral slip angles of front and rear wheels can be expressedwith this model.

As for the vertical dynamics one-dimensional model is shown on figure 5 as a basis for vertical vehicle representation [3, 8]. Depending on the research needs, beside the body mass this model is upgraded with the mass of the wheel, and another for the user seat, as a quarter vehicle presentation. Also, the system is multiplied by two if single track is considered or by four if a complete car is considered.



- Equation of vertical motion - oscillation

$$m \cdot \ddot{z} = F_{pr} + F_A$$
$$m \cdot \ddot{z} = c \cdot (z - h) + k \cdot (\dot{z} - \dot{h}) \tag{7}$$

Figure 5. Single mass oscillatory system

4. VEHICLE MODELS IN TRAFFIC SIMULATIONS

The approach of development of presented models is suitable for testing single vehicle in various conditions and at various maneuvers. When it comes to traffic simulations where many vehicles are included, not every aspect from vehicle dynamics can be considered within atraffic model. Interaction between vehicles is important in traffic.Also, driver behavior is another additional factorthat has an impact.Microscopic traffic models study the behavior of every individual vehicle in relation of otherswithin a traffic flow.For that purpose different car-following modelshave been developed,which are used in traffic simulation tools [5, 6, 7, 16, 17]. These models are upgraded so that themicrosimulation includes lane changing and gap acceptance model.

Car following model describes how each vehicle interacts with the previous and the following vehicle from the same lane.

Line changing model includes series of conditions for deciding when a vehicle could change the laneand about the urgency of changing it. Under the line changing model, gap acceptance model is included, which measures the distance that will occur between the subject and the leading vehicle and between the subject and the following vehicle in the new lane. The calculated distance is compared if it is in safe limits for making a maneuver.

Analysis of these models [5, 6] showed that only longitudinal parameters of vehicle dynamics are included in traffic modeling.Vehicle parameters included in traffic simulation toolsare:

- vehicle category,
- vehicle length,
- maximum velocity,
- maximum acceleration / deceleration, and also
- actual position of the vehicle in the network, velocity and acceleration.

The characteristic of the driver behavior is taken through the memory and psycho-physical sensitivity thresholds of the driver.The interdependence of driver-vehicle units is characterized with reference to leading and following vehicles on current and adjacent lanes, reference to current link and next intersection and to next traffic signal.

5. ANALYSIS OF VEHICLE AND ROAD PARAMETERS

The aspects of vehicle dynamics given above in section three are just the basics in the field. For example, mechanics of the tire, the contact between the tire and the road are not mentioned above, but have significant influence on vehicle stability [9]. If we identify the main parameters that affect vehicle performance such asmaximum acceleration / deceleration or maximum uphill, braking distance and time, lateral acceleration and yaw velocity and limit velocities of traction and rollover, they include:

- mass parameters (total, empty and mass distribution on axles),
- geometrical parameters (length, width, height, wheelbase, distance from front axle to the center of mass, height of the center of mass, front and rear track),
- powertrain characteristics (power at rpm and torque at rpm),
- transmission parameters (final drive and selected gear ratio),
- tire / wheel parameters (rolling radius, lateral and vertical stiffness).

Beside the physical parameters of the vehicle there are also road parameters which have impact of vehicle performance and stability. These include:

- type and the condition of road surface which are expressed bycontact friction coefficient and adhesion coefficient,
- uphill of the road, which is given with gradient in percentage,
- lateral slope of the goad expressed in angular degrees and
- curvature radius, if the road is not straight.

In traffic modeling and simulation hundreds of vehicles are included, so it will be unreasonable to include all aspects of vehicle dynamics(longitudinal, lateral and vertical). Therefore, a selection has to be made to neglect the factors that have insignificant impact, but not to miss any significant factor for stability and safety. As a first stepvertical dynamic can be excluded.It is justified by the fact that in cities and motorways, where traffic tools apply,the road surface is asphalt and in good condition.

Vehicle models used in traffic simulation tools define only longitudinal dynamics, but not entirely. The analysis of parameters used in traffic models shows that there is some insecurity in simulation results of vehicles' behavior, due to exclusion of some influential parameters.The insecurities in results can be explained as follows:

- Whether vehicles are traveling on a horizontal road or uphill, performance in terms of acceleration and braking are equal, which is not the case in reality.
- Acceleration and braking performance is not the same in different weather conditions, which is not included. The condition of aroad surface (dry, wet or frozen) has a great impact on these performances and generally on vehicle stability.

- Driving in curvature is another aspect which is not considered in traffic models,but affects the vehicle performance.In such a maneuver lateral dynamics is particularly significant for vehicle stability.

6. CONCLUSIONS

The network approach used for road infrastructure presentation in traffic modeling provides sufficiently good results, but there is still a space for further improvement.Road network could be upgraded with properties which are related to the type and the condition of the road surface. Vehicle models could also be improved through involvement of additionalvehicle influential technicalparameters.The improvement of the traffic models with these parameters could contribute to more realistic results regarding the vehicles' behavior in urban areas and motorways.

These improvements could increase the efficiency and the significance of the traffic simulation tools in terms of prediction and improvement of traffic flow and safety.Also, they will give more realistic representation of the exhaust emission that can be used for improvement of measures for environmental protection.

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