Traffic Flow Theory Milestones in Developing the TEXAS Model for Intersection Traffic in the Early 1970s

By

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TEXAS Model for Intersection Traffic

• Dr. Clyde E. Lee was the faculty member who conceived the idea of applying the University of Texas at Austin’s (UT) new Control Data Corporation (CDC) 1604 mainframe digital computer for simulating traffic flow through an intersection in the late 1960s

• Dr. Thomas W. Rioux was leader of the team of graduate students that developed the TEXAS Model and has been upgrading the TEXAS Model since its initial development
TEXAS Model for Intersection Traffic

- Dr. Guido Radelat of FHWA suggested the name Traffic EXperimental and Analytical Simulation Model for Intersection Traffic (TEXAS Model)
- Source code released under the GNU General Public License in 2005 by UT
- The TEXAS Model is being enhanced to include Connected Vehicle messages by Harmonia Holdings Group and Dr. Rioux to be a test bed for Connected Vehicle applications
Triangular Acceleration

• The uniform acceleration model did not match observed behavior accurately when considered on a microscopic scale

• A linear acceleration model was investigated

• Comparisons of this model with observed data indicate excellent agreement

• Starting from a stopped condition, a driver-vehicle unit will use a maximum positive jerk rate until it reaches the maximum acceleration then the driver-vehicle unit will use a negative jerk rate until the acceleration is zero at the driver-vehicle unit’s desired speed

• The maximum acceleration is defined by the driver’s desired speed and vehicle capabilities
Triangular Acceleration

Uniform versus Linear Acceleration and Observed Data
Triangular Acceleration

Triangular Acceleration Model

ACCELERATION

TIME

JERK
Triangular Deceleration

• The uniform deceleration model did not match observed behavior accurately when considered on a microscopic scale
• A linear deceleration model was investigated
• Comparisons of this model with observed data indicate excellent agreement
• Starting from a moving condition, a driver-vehicle unit will use a maximum negative jerk rate until it reaches the maximum deceleration when the driver-vehicle unit stops
• The maximum deceleration is defined by the driver-vehicle unit’s current speed and vehicle capabilities
Triangular Deceleration

- If a driver-vehicle unit is to decelerate to a stop, the time to stop and then the distance to stop is calculated each time step increment using current speed, current acceleration/deceleration, and current maximum deceleration.

- A deceleration to a stop is initiated when the driver-vehicle unit’s distance to the location for a stop becomes less than or equal to the distance to stop.
Triangular Deceleration

Uniform versus Linear Deceleration and Observed Data
Triangular Deceleration Model
Equations of Motion

With the development of the triangular acceleration and triangular deceleration models, it was clear that the equations of motion had to include jerk rate as follows:

\[
\begin{align*}
AN &= AO + J \cdot DT \\
VN &= VO + AO \cdot DT + 1/2 \cdot J \cdot DT^2 \\
PN &= PO + VO \cdot DT + 1/2 \cdot AO \cdot DT^2 + 1/6 \cdot J \cdot DT^3
\end{align*}
\]

where:

- \(AN\) = acceleration/deceleration new in \(ft/sec/sec\)
- \(AO\) = acceleration/deceleration old in \(ft/sec/sec\)
- \(DT\) = time step increment in seconds
- \(J\) = jerk rate in \(ft/sec/sec/sec\)
- \(PN\) = front bumper position new in feet
- \(PO\) = front bumper position old in feet
- \(VN\) = velocity new in \(ft/sec\)
- \(VO\) = velocity old in \(ft/sec\)
Car Following

The non-integer, microscopic, generalized Gazis-Herman-Rothery (GHR) car-following model was selected as follows:

\[
\begin{align*}
\text{RelPos} & = \text{PVPos} - \text{PO} \\
\text{RelVel} & = \text{PVVel} - \text{VO} \\
\text{AN} & = \frac{\text{CarEqA} \times \text{VO}^{\text{CarEqM}}}{\text{RelPos}^{\text{CarEqL}}} \times \text{RelVel}
\end{align*}
\]

where:
\[
\begin{align*}
\text{AN} & \quad \text{current driver-vehicle unit acceleration/deceleration new in ft/sec/sec} \\
\text{CarEqA} & \quad \text{user-specified GHR Model Alpha parameter (min=1, def=4000, mx=10000)} \\
\text{CarEqL} & \quad \text{user-specified GHR Model Lambda parameter (min=2.3, def=2.8, max=4.0)} \\
\text{CarEqM} & \quad \text{user-specified GHR Model Mu parameter (min=0.6, def=0.8, max=1.0)} \\
\text{PO} & \quad \text{current driver-vehicle unit front bumper current position old in feet} \\
\text{PVPos} & \quad \text{previous driver-vehicle unit rear bumper position in feet} \\
\text{PVVel} & \quad \text{previous driver-vehicle unit velocity in ft/sec} \\
\text{RelPos} & \quad \text{relative position in feet} \\
\text{RelVel} & \quad \text{relative velocity in ft/sec} \\
\text{VO} & \quad \text{current driver-vehicle unit velocity old in ft/sec}
\end{align*}
\]
Car Following

A conservative car-following distance is defined as follows:

\[ \text{RelVel} = \text{PVVel} - \text{VO} \]
\[ \text{CarDis} = \left( 1.7 \times \text{PVVel} + 4 \times \text{RelVel}^2 \right) / \text{DrivChar} \]

where:

- \( \text{CarDis} \) = car-following distance in feet
- \( \text{DrivChar} \) = user-specified driver characteristic
  \(<1=\text{slow}, \: 1=\text{average}, \: >1=\text{aggressive})\)
  \((\text{min}=0.5, \: \text{max}=1.5)\)
- \( \text{PVVel} \) = previous driver-vehicle unit velocity in ft/sec
- \( \text{RelVel} \) = relative velocity in ft/sec
- \( \text{VO} \) = current driver-vehicle unit velocity old in ft/sec
Car Following

• If the relative velocity $\text{RelVel}$ is greater than or equal to zero (the previous driver-vehicle unit is going faster than the current driver-vehicle unit) and the relative position $\text{RelPos}$ is greater than some minimum value then the driver-vehicle unit is allowed to accelerate to its desired speed

• If the relative position of the vehicle $\text{RelPos}$ is less than or equal to zero then emergency braking is applied

• If the relative position of the vehicle $\text{RelPos}$ is greater than the 1.2 times the car-following distance $\text{CarDis}$ then the driver-vehicle unit is allowed to accelerate to its desired speed

• If the previous driver-vehicle unit is decelerating then calculate where it will stop and calculate the deceleration to stop behind the driver-vehicle unit ahead when it stops and if this deceleration is less than the car following deceleration then use it

• If the traffic signal changed from green to yellow and the current driver-vehicle unit decides to stop on yellow then calculate a deceleration to a stop at the stop line

• If the traffic signal is yellow and the driver-vehicle unit previously decided to stop on yellow then continue a deceleration to a stop at the stop line
Intersection Conflict Checking

• Intersection Conflict Checking (ICC) is the algorithm that determines whether a driver-vehicle unit, seeking the right to enter the intersection, has a predicted time-space trajectory through the intersection that does not conflict with the predicted time-space trajectory through the intersection of all other driver-vehicle units that have the right to enter the intersection.

• If this vehicle’s rear can safely go in front of the other vehicle or this vehicle’s front can safely go behind the other vehicle then there is no conflict.
Intersection Conflict Avoidance

• Intersection Conflict Avoidance (ICA) is the algorithm used to simulate the behavior of driver-vehicle units that have the right to enter the intersection and try to maintain a non-conflict time-space trajectory through the intersection with the predicted time-space trajectory through the intersection of other driver-vehicle units that have the right to enter the intersection.

• Adjusts the vehicle’s speed to maintain the previously detected gaps through the intersection.
Sight Distance Restriction Checking

• The user defines the coordinates of all critical points needed to locate sight obstructions in the intersection area.

• The TEXAS Model Geometry Processor calculates the distance that is visible between pairs of inbound approaches for every 25-foot increment along each inbound approach.

• The time required for a fictitious driver-vehicle unit, traveling at the speed limit of the approach, to travel from a position that is just visible on the inbound approach to the point of intersection conflict is predicted.
Sight Distance Restriction Checking

- The time required for the driver-vehicle unit being examined to travel to the point of intersection conflict is predicted.
- If the unit being checked may not safely pass through the point of intersection conflict ahead of the fictitious driver-vehicle unit then it may not clear its sight distance restrictions and continues on a deceleration to a stop at the stop line.
Lane Changing

• In the early 1970s, Mr. Ivar Fett collected and analyzed the field data, developed the original lead and lag gap-acceptance decision models, and used a cosine curve for the lateral position for a lane change.

• Dr. Rioux developed the concept of distinguishing between two types of lane changes: (1) the forced lane change wherein the currently occupied lane does not provide an intersection path to the driver-vehicle unit’s desired outbound approach and (2) the optional lane change wherein less delay can be expected by changing to an adjacent lane which also connects to the driver-vehicle unit’s desired outbound approach.

• Later, Dr. Rioux added cooperative lane changing and a lane change to get from behind a slower vehicle.
Crashes

• If the front bumper position of the driver-vehicle unit (lag driver-vehicle unit) is greater than the rear bumper position of the driver-vehicle unit ahead (lead driver-vehicle unit) then there is a crash; originally, only lead-lag crashes were detected and were called “clear zone intrusions”

• The lag driver-vehicle unit defied physics by placing itself 3 feet behind the lead driver-vehicle unit traveling at the speed of the lead driver-vehicle unit and with zero acceleration/deceleration and jerk rate and the traffic simulation continued normally
Crashes

• In 2008, Dr. Rioux added the option to stop a driver-vehicle unit involved in a “major” crash using crash deceleration and remain stopped for the remainder of the simulation.

• Additionally, a crash between driver-vehicle units on different intersection paths was detected.

• Logic was added to cause other driver-vehicle units to react to driver-vehicle units involved in a “major” crash by slowing down as they passed the crash or to take evasive actions after they had been delayed for some response time.
Questions 🤔