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Physics of Traffic Flow

L. C. DAVIS, Retired

The Texas A&M Transportation Institute estimated that traffic congestion cost the United States $121 billion in 2011 (the latest data available). The cost is due to wasted time and fuel. In addition to accidents and road construction, factors contributing to congestion include large demand, instability of high-density free flow and selfish behavior of drivers, which produces self-organized traffic bottlenecks. Extensive data collected on instrumented highways in various countries have led to a better understanding of traffic dynamics. From these measurements, Boris Kerner and colleagues developed a new theory called three-phase theory. They identified three major phases of flow observed in the data: free flow, synchronous flow and wide moving jams. The intermediate phase is called synchronous because vehicles in different lanes tend to have similar velocities. This congested phase, characterized by lower velocities yet modestly high throughput, frequently occurs near on-ramps and lane reductions. At present there are only two widely used methods of congestion mitigation: ramp metering and the display of current travel-time information to drivers. To find more effective methods to reduce congestion, researchers perform large-scale simulations using models based on the new theories. An algorithm has been proposed to realize Wardrop equilibria with real-time route information. Such equilibria have equal travel time on alternative routes between a given origin and destination. An active area of current research is the dynamics of connected vehicles, which communicate wirelessly with other vehicles and the surrounding infrastructure. These systems show great promise for improving traffic flow and safety.