Office of Operations
Research and Development

Microscopic Traffic Simulation Models and Software

"An Open Source Approach"

The ***E***TFOMM (Enhanced Transportation Flow Open-source Microscopic Model) ***C***loud ***S***ervice (ECS) is a software product sponsored by US DOT under the "Microscopic Traffic Simulation Models and Software-An Open Source Approach" research project (SBIR DTRT5708C10060, DTRT5711C10037 and DTRT5715C10005). ***E***TFOMM is centered on the core microscopic traffic ***S***imulation ***E***ngine (ESE), a graphical user input editor (ETEditor), a 3D traffic visualization tool (ETAnimator), and a database in cloud service environment, as shown in Figure 1. ETEditor and ETAnimator are developed under a grant from the Kentucky Cabinet for Economic Development, under the Grant Agreement KSTC-184-512-13-155 with the Kentucky Science and Technology Corporation.

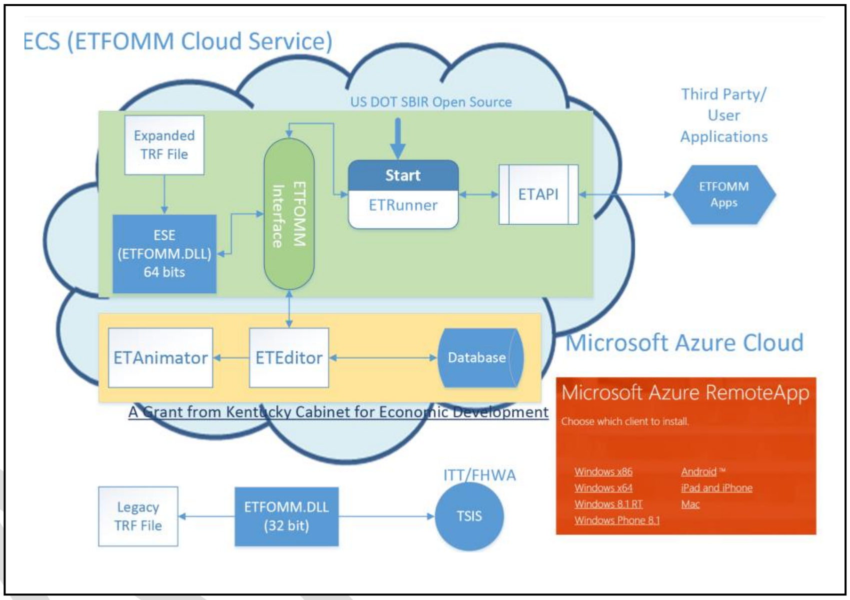


Figure 1 ETFOMM and its Major Components

ESE is open source software, which inherits 40 years of FHWA development of traffic simulation algorithms and flow theories while overcoming CORSIM's limitations in supporting research. ESE utilizes state-of-the-art advanced computing technologies, such as a native 64-bit stand-alone application, explicit parallel computing and multi-processor capabilities on multiple platforms (Windows/Linux/MacOS).

ESE includes ***ET***FOMM ***A***pplication ***P***rogramming ***I***nterface (ETAPI) that provides communications between ETFOMM's core simulation engine and user-developed applications (Apps) through ETRunner, an Windows console program. ETAPI is built upon Microsoft's most recent Windows Communication Foundation (WCF) technology. ETAPI supports a distributed platform with multiple network protocols, is compatible with almost any programming language, and facilitates mobile computing (e.g., smartphones and tablets) and cloud computing through SOAP/HTTP. ETFOMM provides the robust platform and most flexibility for researchers and academic users to advance their transportation research.

ESE maintains the research community's confidence in traffic simulation through its open-source approach. Traffic simulation software is a special set of software with many human-factor-related "expert rules." The open source approach offers the transportation research community a window to examine those rules, fix bugs, add new rules, or even just avoid the misuse of the software in their research projects. Most significantly, any researcher can share the software enhancements with the transportation research community. Researchers are able to not only modify and add new rules to make the software work better but also to accommodate new technologies and new traffic operation developments.

ETEditor provides a very versatile input editor that allows users to directly input roadway geometric data and elevation data and to automatically build highway and surface street networks. 3D tool ETAnimator has been created on state-of-the-art 3D visualization technologies. 3D visualization technologies have advanced the realization of Virtual World in traffic animation. A database has been designed and created to save simulation input and output data, as well as to effectively manage the large amount of vehicle trajectory data in the database.

ECS is hosted on the Microsoft Azure platform, but the database can be deployed on a local server to alleviate privacy concerns. ECS is expected to profoundly benefit transportation educators and researchers. ETFOMM has been tested in an MS DOT Integrated Corridor Management Project and is being used in a Connected Vehicle Research project at the Saxton Transportation Operations Lab, at FHWA's Turner Fairbank Highway Research Center. ETFOMM will support Connected Vehicle communication-in-the-loop simulation and traffic signal controller hardware-in-the-loop simulation.

Date

Publication No. FHWA-HRT-##-###
HRDO-##/##-##(#M)E

Unified Freeway and Street Simulation Algorithms

- Pitt/IDM/ACC/CACC/Mixed car following logics
- Collision avoidance
- Discretionary lane changing
- Mandatory lane changing
- Lane change acceptable risk
- Path following vehicles

Unique Features

- Compatibility with existing TRF files
- Export to TRAFVU
- Freeway diversion (Integrated Corridor Management)
- Lane width effect on desired freeway speed
- Runs on Linux (theoretically Mac OS and more)
- Vehicle-type exclusions by lane
- Complicated freeway-to-freeway direct connections without dummy links/nodes (Figure 2)
- No 8000 entry and exit nodes
- Variable time steps (could be as small as 0.01 s)
- Allows path/turning percentage based simulation
- Basic bicycle/pedestrian operation
- Bus operations on Surface Street/Freeway
- Remodeled Intersection Vehicle Movement Logic

Advanced Computing Features

- Native 64 bit applications
- Multiple-Core/Thread SSAM Conflict Analysis
- Parallel processing Surface/Freeway vehicles
- Multiple run could be deployed on different CPU simultaneously
- Distributed Architecture Through WCF

Advanced Traffic Signal Control and Beyond

- Interfacing with enhanced FHWA Open Source Traffic Signal Controller Algorithm
- Standard NEMA Operations
- Coordination and Transition Logic
- One Controller/Complexed Intersections
- Direct Texas 3/4 Diamond Interchange Phases
- NTCIP based hardware-in-the-loop, NO CID needed

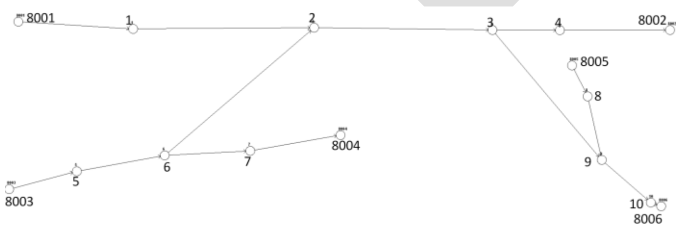
Model Any Modern Network: No limitations!

	CORSIM		ETFOMM	
Characteristic	NETSIM	FRESIM	Street	Freeway
Bus routes	500		U	U
Buses	2000	2000	U	
Data stations	N/A	2000	N/A	
Detector stations	N/A	2000	N/A	
Detectors	7000	6000	U	
Detectors for a Metering Signal	N/A	10	N/A	
Entries per Segment	N/A	100	N/A	
Exits per Segment	N/A	100	N/A	
Incidents	N/A	100	N/A	
Links per Segment	N/A	200	N/A	
Nodes	8999	8999	U	
Ramp metering signals	N/A	4000	N/A	
Events	200	N/A	U	N/A
Through lanes	7	5	20	20
Number of turn pockets	2	N/A	5	N/A
Variable turning pocket lengths	No	N/A	5	N/A
Auxiliary lanes	N/A	6	N/A	10
Variable aux-lane lengths	N/A	No	N/A	5

- U=Unlimited

Support to Safety Applications

- Red light runner as an MOE
- DCS dilemma zone allocation-built in
- Integrated Surrogated Safety Assessment Model



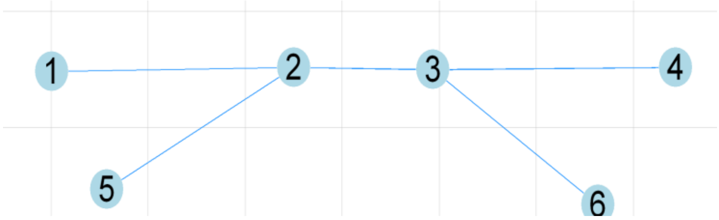


Figure 2 CORSIM (left) and ETFOMM (right) Freeway Weaving Link/Node Diagrams

Most Advanced APIs for Mobile/Distributed Computing

- Components based, related to real world, such as vehicles, detectors, traffic control systems, etc.
- Both data and function access for commonly used components
- Multiple network protocol support (HTTP, TCP/IP, SOAP)
- Cross platform and mobile interface (through HTTP/SOAP)
- Almost any programming language that supports WCF: C#, C++, VB, html, Python, etc.
- API functions that allow the executive system to access and modify simulation data, such as vehicle desired speed, turn code, destination, etc., and to access and modify fixed-time signal parameters, such as duration of green time or current interval
- API Examples showing how to interface with user developed traffic signal control algorithms, lane changing/car following algorithms through ETAPI.

Example Research Projects

In the Saxton Transportation Operations Lab, ETFOMM is used to develop, debug, test and evaluate innovative safety and mobility applications:

- Arterial traffic progression/optimization models with connected vehicle information
- Feasibility of Low Cost Solution to Decision Control system for dilemma zone Safety
- Infrastructure Based Speed Harmonization at freeway ramp merging areas.

In the first project, an arterial traffic progression/optimization model is established by changing split and offset at coordinated signalized intersections. The model combines traditional traffic detection and information from Basic Safety Message sent from Connected Vehicles, propagates traffic signals from one intersection to another, optimizes offset and adjusts split in real time. The real time traffic signal timing plans are sent back to API at actuated traffic signal controller inside ETFOMM, which generates the measures of effectiveness. In a case study, the proposed algorithms outperform TRANSYT-7F by about 50% at major streets and at least 25% in control delay with Connected Vehicle penetration rates as small as 10%.

In the second study, ETFOMM is used to provide detector and traffic signal status for DCS originally developed by the Texas Transportation Institute that enhances the dilemma zone safety. Once DCS decides to extend or terminate the green time to avoid vehicles trapped in the dilemma zone, it sends back the request to the actuated signal controller inside ETFOMM. Multiple runs of simulation and statistical analysis of simulation results indicates that DCS reduces the number of stops and red light runners.

In the third task, detector data from ETFOMM provide inputs for a model to minimize the total freeway and ramp delay. The model outputs the speed reductions for freeway vehicles in order to create gaps for ramp vehicles to merge. The proposed speed reductions are implemented in ETFOMM. Evaluation from ETFOMM indicates the strategy can significantly reduce delays and increase the throughput.

Educational Examples in Transportation Engineering

At the Department of Civil and Environmental Engineering, Mississippi State University, undergraduate students in *Traffic Engineering* class have learned and used ETFOMM to analysis level of services for intersections with actuated control traffic signals and freeway sections with weaving, merging and diverting. Students also collect field data to update traffic signal timing plans and evaluate alternative timing plans in ETFOMM. In *Traffic Simulation and Traffic Management* course and *Traffic Flow Theory* course, graduate students created their own algorithms to interface with ETFOMM. Finally, one Ph.D. student created traffic signal optimization models using connected vehicle. His models and algorithms used many ETFOMM API functions and interfaced with ETFOMM. Two Ph.D. students are working to interface their traffic optimization models with ETFOMM.

Support for Connected/Automated Vehicle and Other Research

- Most advanced APIs
- Advanced Traffic Controller and Beyond
- Communications-in-the-loop (Working-in-the-progress)
- IDM/ACC/CACC car following logic built in
- A Distributed Development Environment
- Integrated TCA for BSM for Connected Vehicles
- Recovery functions to convert BSM to vehicle trajectories

Future Functions (2016-2017)

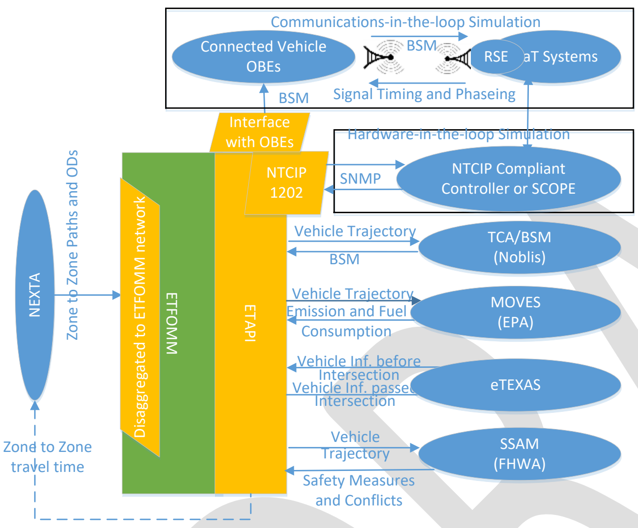


Figure 3 ETFOMM and Other FHWA Software

- Communication in-the-loop simulation
- SPaT (Signal Phasing and Timing) Integration
- Specific Vehicle Movement Logic at Roundabout/Interchanges (Traditional and Alternatives)/Complex Intersections
- Surrogate Safety Assessment Model Enhancement
- Built-in Fuel Consumptions and Emission from EPA Models
- HOT/DMS/VMS

Open-Source Source Code Download Link

- http://www.itsforge.net/etfomm/
- http://www.sourceforge.net/etfomm/
- http://www.itsforge.net/ssam
- http://www.etfomm.org

SSAM and Intersection Modelling

We have converted the latest FHWA version of SSAM from Java to C++, and added parallel computing capabilities. We also created a user friendly graphical interface to run SSAM. Our fidelity tests have indicated that Java and C++ generate identical safety measures and conflicts. The parallel enhanced C++ version of SSAM is about 90% faster than the original Java version (results may vary).

We also significantly modified the ETFOMM intersection simulation logic. CORSIM/ETFOMM employed gap acceptance models at insertions, but intersection shapes and sizes are not well defined in the model. Vehicles looked at gaps and proceeded through the intersection when gaps were acceptable. Now, vehicle movements are modeled more precisely within intersections. On top of those changes, we have added roundabout and turning way (with/without island) modeling capabilities.

In the coming month, we will first convert the rest of the Java conflict display and statistical analysis functions. We will add more safety measures, such as multiple PET (mPET), multiple TTC (mTTC), and probability of unsuccessful evasive action P(UEA). We will further enhance the SSAM user's graphic experiences and enhance usability. We propose to add bar chart, Heat Map, Contour Map, Zooming and displaying user defined/selected areas, to display conflict points. Finally, we will add functions to reorganize more safety measures, such as interchange and traffic signal timing related. The latter of which will afford SSAM to help develop signal timing plans, especially in considering yellow and red intervals.

Academic/University License Granted (Free ECS)

- Mississippi State University
- University of Kentucky

Contact (including Free University Wide Deployment)

- FHWA Project Manager: Dr. Joe Bared
  email: Joe.Bared@dot.gov
  phone: 2024933314
- Software Developer
  New Global Systems for Intelligent Managnt Corp.
  Dr. Li Zhang
  email: ngsim@ngsim.com
  phone: 6623415725