INDEX

Note: Page numbers followed by f indicate figures and t indicate tables.

Α	neural network model
Ackerman angle, 279	artificial neural networks, 241-242
Acoustic/ultrasonic sensors	back-propagation neural network, 242
advantages, 10	data collection, 243
data collection, 10	driver's operational control, 242
disadvantages, 10	first input-output pattern, 243
parking sensor, 9-10	neurons, 241-242
pedestrian/vehicle and sensor distance,	training process, 243
9-10	Pipes model, 183-187
Aerial/satellite imaging	psychophysical model (see VISSIM)
advantages, 11	driver's operational control, 237
data collection, 11	driving regimes, 239
disadvantages, 11	illustration of, 238f
manned/unmanned helicopters, 10-11,	operating point, 239
11 <i>f</i>	psychological activities and physical
vehicle counts, vehicle speeds and traffic	behavior, 239
density, 10-11	vehicles collision, 237
AIMSUN, 245-247	rule-based model, 240-241
	Cell transmission model (CTM)
В	divergence scenario, 146-147
Bernoulli model	mainline scenario, 140-142
compressible fluid mechanics, 267	merger scenario
empirical comparison, 268	demand exceeds supply, both upstream
fluid velocity, 265–266	links congestion, 145
ideal gas law, 266	demand exceeds supply, one upstream
principle, 262, 265-266	link congestion, 144
Boltzmann equation	freeway merge, 142f
conservation law, 370	queuing model, 142
initial and boundary conditions, 370–371	supply exceeds demand, 143
longitudinal control model, 370	minimum principle, 139-140
rongradmar comror model, e, s	taxonomy of, 170f
•	1964 Chevrolet Corvair, 268-269
C	Connected vehicle technology (CVT),
California Vehicle Code, 183, 185-186	261-262
Car-following models	Conservation law
CARSIM model, 239-240	continuity equation
Forbes model, 187-188	finite difference, derivation I, 72-74
macroscopic benchmarking, 191-193	finite difference, derivation II, 74-75
microscopic benchmarking, 188-191	fluid dynamics, derivation III, 75-77
microscopic models, taxonomy of, 246f	roadway traffic, 72

Conservation law (Continued)	high computational efficiency and
scalar conservation law, derivation IV,	modeling fidelity, 275
77–78	modeling lateral movement, 278-279
three-dimensional representation of	modeling longitudinal movement
traffic flow, derivation V, 78	aerodynamic drag, 277
first-order dynamic model, 79-80	braking performance, 277
flow-speed-density relationship/identity,	grade resistance, 278
71	modeling acceleration performance,
mass conservation, 72	276
one-dimensional compressible fluid, 72	Newton's second law of motion, 276
pairwise relationships/equilibrium	steering angle, 275-276
models, 71	throttle position, 275-276
PDE, 92	DynaMIT, 361-362
traffic flow theory, 71-72	DYNASMART, 361-362
traffic states, 72	
Continuum flow models	E
Kerner and Konhäuser's model, 166	Edie model, 59-62
LWR model, 166	Energy conservation, 164, 168, 371-372
Michalopoulos et al. model, 166	Engine modeling
Phillips's model, 166	accessibility, 262
PW model, 166	accuracy, 262
relative merits of, 167-168	calibration, 262
Treiber et al. model, 167	computational efficiency, 262
Zhang's model, 166	cross-comparison of, 273
Control theory, 360, 363	CVT, 261-262
CORQ, 362	existing engine models
CORSIM, 245-247	direct-injection spark-ignition engine
Coulomb's law, 207, 287-288, 341-342	model, 263
CTM. See Cell transmission model (CTM)	filling and emptying method, 263
CVT. See Connected vehicle technology	hybrid vehicle modeling, 263
(CVT)	IC engines, 262-263
_	linear engine model, 263-264
D	spark-ignition engine, 263
d'Alembert solution, 88-89	teaching purpose, 263-264
Del Castillo model, 332	formulation, 262
Desired measure model, 245-247	internal combustion engines, 261-262
Deterministic models, 360-361	mathematical engine models
Discrete choice model	Bernoulli model, model III, 265-268
lane-changing model, 175	parabolic model, model II, 265
lateral direction, 178	polynomial model, model I, 264
route-choice model, 173-175	parameter values, 273
Drake et al. model, 203, 205, 332	validation and comparison of
Drew model, 204, 205	automotive engines, 268-269
Dynamic interactive vehicle (DIV) model	1964 Chevrolet Corvair engine,
automotive engineering, 275	268-269, 271 <i>f</i>
brake pedal position, 275-276	empirical engine power and torque
calibration and validation, 279-280	curves, 268-269

2006 Honda Civic engine, 268-269,	decouples equations, 297
270 <i>f</i>	directional response, 297-300
MAPE, 271-272	forces, 297
2008 Mercedes CLS engine, 268-269,	generic theory, 296
270 <i>f</i>	lateral direction, 299-300
model I, 269	longitudinal direction, 297-299
model II, 269	Occam's razor, 296
model III, 269	traffic flow, physical basis of
2006 Pagani Zonda engine, 268-269, 270f	electromagnetic phenomena, 287-288
technical specifications, 269t	mechanics phenomena, 285-287
Equilibrium traffic flow models	physical laws and social rules, 284
multiregime models, 59-62, 62 <i>t</i> , 64 <i>f</i>	statistical mechanics phenomena,
single-regime models	289-291
comparison of, 61f	three systems, 285f
equilibrium/steady-state relationship,	transportation system, 284
51-52	wave phenomena, 288-289
flow, speed and density, 52-55	Forbes model
free-flow speed, 58-59	applications (see Pipes model)
Georgia NaviGAtor, 51	macroscopic benchmarking, 191-193
Greenshields model, 55-58	perception-reaction time, 187-188
one-equation models, 59	properties (see Pipes model)
point sensor, 51, 53f	safety rule, 187
traffic speed, 51-52	steady-state model, 331-332
video images, 51	FREFLO
speed-density relationship	numerical solutions
observed mean and standard deviation,	conservation law, 135
62-63, 65 <i>f</i>	dynamic speed-density relationship,
scattering effect, 62-63	136
three-dimensional representation, 65f	equilibrium speed-density relationship, 137
F	macroscopic traffic simulation model,
Federal Motor Carrier Safety	135
Administration, 280	PW model, 163-164
Field theory	FREQ, 137, 362
congestion, 301-302	
driver's interaction, 294-295	G
driver's responsiveness, 292-293	Gap-acceptance models, 245, 360-361
driver's strategy, 295-296	General Motors (GM) models
existing knowledge base	development of
engineering disciplines, 302-303	driver's control maneuver, 195
physical science, 304	GM1, 196
traffic flow theories, 302	GM2, 196-197
mobility, 301	GM3, 197
motivation, 283-284	GM4, 197-198
physical field, 291-292	GM5, 198
simplification of	stimuli and sensitivity, 195-196

General Motors (GM) models (Continued)	disadvantages, 9
limitations of	satellite-based navigation system, 8-9
intimate pair, 208-209	spatial-temporal points, 9
mechanism of motion, attraction, 207	triangulation, 8-9
slow start, 208, 208f	vehicle's trajectory, 19-21, 21f
universal car following, 207	Gradient catastrophe, 96
macroscopic benchmarking, 205	Greenberg model, 201-202, 205, 332
microscopic benchmarking, 198-199	Greenshields model
microscopic-macroscopic bridge	dynamic traffic flow modeling, 58
Drake et al. model (Northwestern	flow-density relationship, 56f
Model), 203	flow-density-speed relationship, 57f
Drew model, 204	fundamental diagram, 57-58, 60f
GM5, 201	highway capacity and LOS, 58
Greenberg model, 201-202	LWR model, 115-116
Greenshields model, 203	microscopic-macroscopic bridge, 203
macroscopic equilibrium models, 204	speed-density relationship, 55, 55f
microscopic car-following models, 204	speed-flow relationship, 56f, 57
Pipes and Forbes models, 204	traffic flow theory, 58
Pipes-Munjal model, 203	vehicular traffic flow, 57-58
single-regime models, 201 <i>t</i>	
Underwood model, 203	Н
traffic flow theory, 195	High-order models
Wilson, Charles, 195	continuum flow models, 166-167
Georgia State Route 400 (GA400) data, 13-15	first-order partial differential equation, 163
Gipps model	Kerner and Konhäuser's model (1993),
fundamental diagram, 219f	164-165
macroscopic benchmarking, 218	Kühne's model (1984), 164
microscopic benchmarking, 216-218, 217f	macroscopic models, taxonomy of, 168-169, 170 <i>f</i>
model formulation	mass/vehicle conservation, 163
car-following scenario, 212f	Michalopoulos et al. (1993) model, 165
Forbes rule, 211	Phillips's model (1979), 164
free-flow regime, 214	PW model (1971), 163-164
perception-reaction process, 212	Treiber et al. (1999) model, 165-166
Pipes rule, 211	Zhang's model (1998), 165
quadratic inequality, 213	Highway Capacity Manual (HCM), 37
safe driving rule, 211	2006 Honda Civic, 268-269
speed choice model, 214	HUTSIM, 245-247
properties of, 215-216	
steady-state model, 331-332	1
Global positioning system (GPS)	IDM. See Intelligent driver model (IDM)
advantages, 9	IF-THEN rules, 244, 245, 360-361
automotive navigation and traffic time	Inductive-loop detectors
studies, 8	actuated signal controller, 4-5
cell phones, 8	advantages, 5
data collection, 9	data collection, 5

disadvantages, 6	shock path and queue tail, 120-121
intersections, 3	shock wave solution
red-light-running camera, 4-5	characteristics method, 117
resonant frequency, 4	fast platoon, 117
Integration, 245-247	kinematic wave, 116
Intelligent driver model (IDM)	shock path, 116-117
desired spacing, 227	slowing down effect, 116-117
fundamental diagram, 232f	slow platoon, 117
macroscopic benchmarking, 230, 230t	traffic flow problems
microscopic benchmarking, 228, 229f,	bottleneck, varying traffic demand,
230 <i>t</i>	123-126, 124 <i>t</i> , 125 <i>f</i>
properties of, 227-228	moving bottleneck, 126, 126t, 127f
Intelligent transportation systems (ITS), 3	Lincoln tunnel, 80
Internal combustion (IC) engines, 261-262	Longitudinal control model (LCM)
	aggressiveness, 332
K	applications
Kalman filter technique, 33	commercial simulation packages, 325
Kinematic waves model, 362	freeway, 326-327
Kosonen model, 245, 347f	macroscopic approach, graphical
KRONOS	solution, 327-329
first-order models, 362	microscopic approach, deterministic
numerical solutions	simulation, 329-330
computerized macroscopic traffic	microscopic approach, random
simulation model, 137	simulation, 330-331
discretization, 138f	service analysis procedure, 325
Greenshields model, 139	traffic phenomena, 325
ramp flows and lane changes, 137	transportation planners, 325
_	desired spacing, 332
L	driving force, 308-309
Lane-changing models, 245, 360-361	empirical results
LCM. See Longitudinal control model	Amsterdam data, 321f
(LCM)	autobahn data, 316-324, 318f
Lennard-Jones potential, 302-303, 303f	cloud density, 317
Level of service (LOS), 58	congested regime, 316-320
Lighthill, Whitham and Richards (LWR)	facility types, 322t
model	free-flow speed and capacity, 316-320
conservation law, 114-115	GA400 data, 316f
dynamic traffic flow model, 113	Highway 401 data, 316-325, 320f
flow-density relationship	Interstate 4 data, 316-325, 317f
free-flow, 122	Newell model, 316-320
kinematic wave, 122	optimized model, 319
moving observer, 122-123, 124 <i>f</i>	PeMS data, 316-324, 319f
shock wave, 122	reverse-lambda shape, 316-320
traffic, 122	traffic flow data, 316
general q-k relationship, 118-120	traffic stream models, 316
Greenshields model, 115-116	traffic stream models, facility types,
RIEMANN problem, 117-118	323 <i>t</i>

Longitudinal control model (LCM)	categories, 175
(Continued)	driver's options, 173
Underwood model, 316-320	driving decisions, 173
Forbes model, 331-332	gap-acceptance decision, 175
General motors models, 331-332	lane-changing decision, 175
Gipps car-following model, 331-332	operational decision, 175, 177f
intelligent driver model, 331-332	route-choice decision, 173-175
macroscopic model, 310-311	strategic level decision, 174f
microscopic model, 309-310	tactical decision, 175, 176f
model properties	notation, 175-177
boundary conditions, 313-314	Modified Greenberg model, 59-62
consistent modeling approach,	Momentum conservation, 164
312-313	Multiscale traffic flow modeling
field theory and Newton's second law	consistent multiscale models, 358-359
of motion, 311	microscopic modeling
model flexibility, 314-316	lateral control model, 368-369
one-equation model, 311	longitudinal control, 366-368
Newell nonlinear car-following model,	macroscopic modeling, 371-372
331-332	mesoscopic modeling, 369-371
Newton's second law of motion, 308-309	modeling scales, spectrum of
Pipes model, 331-332	issues of, 362-363
single-regime category, 332	macroscopic scale, 362
steady-state model, 331-332	mesoscopic scale, 361-362
Van Aerde car-following model, 331-332	microscopic scale, 360-361
vehicle operational control, 308-309	picoscopic scale, 360
	picoscopic modeling
M	component fields, 364
MAPE. See Mean absolute percentage error	driver-vehicle-environment
(MAPE)	closed-loop control system, 363
Mass conservation, 164	driving strategies, 364
Mathematical engine models	perceived field, illustration of, 365f
Bernoulli model, 265-268	traffic simulation, 357-358
parabolic model, 265	zoomable simulation, 357-358
polynomial model, 264	
MATLAB, 329	N
Mean absolute percentage error (MAPE),	Navier-Stokes equation of motion, 163-164
271-272	NaviGAtor system, 13-14
2008 Mercedes CLS, 268-269	Neural network model
Microscopic modeling	artificial neural networks, 241-242
macroscopic benchmarking, 180-182	back-propagation neural network, 242
microscopic benchmarking	data collection, 243
car-following models, 178-179	driver's operational control, 242
hypothetical driving regimes, 178	first input-output pattern, 243
single driving process, 179–180	neurons, 241-242
trial and error, 180	training process, 243
modeling scope and time frame	Neuro-fuzzy hybrid models, 360-361
car-following decision, 175, 177f	Newell model, 316-320, 332

Newell nonlinear car-following model,	applications
331-332	connected vehicle technology, 258,
Newell nonlinear model	258f
fundamental diagram, 225f	emergency management, 259
macroscopic benchmarking, 224, 226t	interactive highway safety design,
microscopic benchmarking, 222-224,	257-258
223f, 224t	transportation forensics, 258-259
Newell nonlinear car-following model,	driver, vehicle and environment
221	closed-loop system, 253, 254f
properties of, 221-222	driver modeling approach, 253-254,
Newell simplified model, 226-227	255 <i>f</i>
Newton's law of universal gravitation, 207	environment information, 254-255
Next Generation Simulation (NGSIM),	field theory, 255
15-17, 245	intelligent agent, 254-255
Northwestern model, 203, 205	interaction, 253
Numerical solutions	roadway traffic, 256
CTM	speed, acceleration and yaw velocity,
divergence scenario, 146-147	256-257
mainline scenario, 140-142	traffic operation, 256-257
merger scenario, 142-146	transportation system, 253-254, 254f
minimum principle, 139-140	vehicle dynamic responses and lateral
discretization scheme	movement, 255-256
cell storage, 135	vehicle feedback, 254-255
free-flow speed, 134	Pipes model
time and space, 133, 134f	applications of
FREFLO	automatic driving, 184-185
conservation law, 135	computer simulation, 185-186
dynamic speed-density relationship,	California Vehicle Code, 183
136	fundamental diagram, 192f
equilibrium speed-density relationship,	macroscopic benchmarking, 191-193
137	microscopic benchmarking, 188-191,
macroscopic traffic simulation model,	190f, 191 <i>t</i>
135	properties of, 186-187
FREQ, 137	steady-state model, 331-332
KRONOS	Pipes-Munjal model, 203, 205
computerized macroscopic traffic	Pneumatic tubes
simulation model, 137	advantages, 8
discretization, 138f	data collection, 7, 8
Greenshields model, 139	disadvantages, 8
ramp flows and lane changes, 137	installation of, 7f
_	short-term traffic engineering studies, 7
P	Poisson arrival pattern, 330-331
2006 Pagani Zonda, 268-269	Prigogine's model, 361-362
Paramics, 245-247	Probabilistic models, 360-361
Partial differential equation (PDE), 83, 102	Psychophysical model
Photoelectric effect, 289	driver's operational control, 237
Picoscopic modeling	driving regimes, 239

Psychophysical model (Continued)	equilibrium/steady-state relationship,
illustration of, 238f	51-52
operating point, 239	flow, speed and density, 52-55
psychological activities and physical	free-flow speed, 58-59
behavior, 239	Georgia NaviGAtor, 51
vehicles collision, 237	Greenshields model, 55-58
	one-equation models, 59
R	point sensor, 51, 53f
Radio-frequency identification (RFID)	traffic speed, 51-52
advantages, 12	video images, 51
data collection, 12	IDM, 227-230
disadvantages, 13	Newell nonlinear model, 221-224
electronic toll collection system, 12, 12f	Newell simplified model, 226-227
identification and tracking, 12	Van Aerde model, 230-233
transponders, 12	Speeds, flow-density relationship
Route-choice models, 173-175, 245	free-flow, 122
Rule-based model. see HUTSIM	kinematic wave, 122
car-following models, 240-241	shock wave, 122
human intelligence, 241	traffic, 122
illustration of, 241f	_
, j	Т
S	Three-regime model, 59-62
Simplified theory of kinematic waves	Traffic flow characteristics
backward wave propagation, 153-154	desired traffic
computational algorithm	density, point sensor data, 32–33
actual departure, 157, 158	field data collection, 31
capacity constraint, 157	HCM, 31
departure, 157	loop detector/video camera, 31
lattice point, 158	space mean speed, point sensor data,
time and space, 156-157	32
traffic flow, 156-157	generalized definition
upstream arrival, 157	flow, mean speed and density, 42
D/D/1 queuing theory, 151	HCM, 37
Derivation V, 151	infinitesimal distance, 38, 38f
forward wave propagation, 152–153	infinitesimal duration, 39, 40f
local capacity, 154	point sensor data, 37
minimum principle, 155, 155 <i>f</i>	space sensor data, 37
on-ramp and off-ramp queuing models,	time-space rectangle, 40 mobile sensor data
159	GPS data, 19, 20 <i>t</i>
segments, 159	
single bottleneck, 155-156	vehicle's speed, 19
traffic dynamics, 151	vehicle's trajectory, 19-21, 21f
triangular flow-density relationship, 152	vehicle's travel time, 19-21 point sensor data
Single-regime models	electromagnetism, 23–24
equilibrium traffic flow models	headway, 23, 24
comparison of, 61f	loop detector data, 23-24, 23f
	1007 40000001 4444, 20 21, 20,

occupancy, 24	signal propagation, 289
on time, 24	wave-particle duality, 289
time mean speed, 24	Traffic sensing technologies
time-space diagram, 22, 22f	classification
traffic count, 22, 24	intrusive, 13
vehicle speed, 24	mobile sensor, 13
relationships	nonintrusive, 13
density and spacing, 28	off-roadway, 13
flow and headway, 28	point sensor, 13
flow, speed and density, 27	space sensor, 13
occupancy and density, 30-31	data sources
time mean speed and space mean	GA400 data, 13-15
speed, 29-30	NGSIM data, 15-17, 16f
space sensor data	ITS, 3
density, 25-26	types
space mean speed, 26	acoustic/ultrasonic sensors, 9-10, 10f
spacing, 25	aerial/satellite imaging, 10-11
vehicle speed, 26	GPS, 8-9, 8f
three-dimensional representation	inductive-loop detector, 3-6
density and space mean speed, 48	pneumatic tubes, 7-8
examples, 44f	RFID, 12-13
intelligent transportation system, 48	VIPS, 6-7, 6 <i>f</i>
N-t diagram, 46f	Traffic stream model, 314
N- t - x region, 47 f	TRANSIMS, 361-362
N-x diagram, 45f	Two-regime linear model, 59-62
vehicle trajectories, 46	
time-space diagram and characteristics,	U
26, 27 <i>f</i> , 27 <i>t</i>	Underwood model, 203, 205, 316-320, 332
Traffic flow, physical basis of	Unified diagram
electromagnetic phenomena	connections, 351–354
car following, 287-288	field theory, 339–340
shying-away effect, 288	macroscopic equilibrium models
tailgating, 288	Del Castillo and Benítez model, 350-351
Maxwell-Boltzmann distribution, 290f	
mechanics phenomena directional flow, 285-286	Drew model, 349
free flow, 286	GM-associated models, 351
Newton's third law of motion, 285	IDM (macroscopic), 348
red light, 286	Kosonen model, 347f
road barriers, 286-287, 287f	Newell model (macroscopic), 348 Pipes-Munjal model, 348-349
physical laws and social rules, 284	Van Aerde model (macroscopic), 348
statistical mechanics phenomena,	Wang et al. model, 349–350
289-291	microscopic car-following models
three systems, 285f	CARSIM model, 344-345
transportation system, 284	Forbes model, 341
wave phenomena	Gipps model, 342–343
harmonic wave, 288	GM models, 341-342
	01.1 1110 00010, 0 11 0 12

Unified diagram (Continued)	range of influence, 89
IDM, 343	conservation law, 99
Newell model, 340-341	entropy condition, 109-110
psychophysical model, 345-346	general solution to wave equations, 87-89
rule-based model, 346-347	gradient catastrophes
Van Aerde model, 344	break time, 99-101
motivation	compression wave, 101
acceleration, 338, 339	expansion wave, 101
deceleration, 338	infinite gradient, 99-101
driver operational control, 338	solution profile, 101, 101f
dynamic car-following model, 338	time-space points, 99-101
gas and brake pedals, 338	mathematical representation
human factors, 338	homogeneity, 85
Newell nonlinear car-following	linearity, 85
model, 337	notation, 84
Newton's second law of motion, 339	order, 84-85
physics, 338	PDE, 83
traffic flow models, 337	properties
picoscopic models, 351	characteristics, 94-96
traffic flow models, 351, 352f	solution, 96
·	rarefaction waves
V	characteristics method, 107
Van Aerde car-following model, 331-332	characteristics without intersection,
Van Aerde model	105 <i>f</i>
fundamental diagram, 235f	conservation law problem, 107
macroscopic benchmarking, 231-233,	empty area, characteristic filling, 106f
233 <i>t</i>	Rankine-Hugonoit jump condition,
microscopic benchmarking, 231, 233t,	107-108
234 <i>f</i>	shock wave solution, 108, 108f
Pipes model and Greenshields model,	time development of, 106f
230	shock waves
properties of, 230-231	characteristic intersections, 102
Video detection system (VDS), 13-14	conservation law, 103
Video image processing system (VIPS)	kinematic waves, 104
advantages, 7	piecewise solution, 102f
data collection, 7	Rankine-Hugonoit jump condition,
detection zone, 6	102, 103-104
disadvantages, 7	shock path, 102, 104, 104f
roadway traffic, 6	solution, wave equation, 90-92
video camera, 6	surface waves, 84f
VISSIM, 245-247	traffic waves, 84f
	traveling waves, 85-86
W	traveling wave solutions, 86
Waves	wave front and pulse, 87
characteristic method, 92-94	wave phenomena, 83
characteristics	wave terminology, 110-111
characteristic lines/characteristics, 90	Wiedmann model, 345, 345f
domain of dependence, 89	"Wrong-way travel," 165