

# ***CORSIM* User's Guide**

**Version 5.0**

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***Prepared by:***

ITT Industries, Inc., Systems Division  
ATMS R&D and Systems Engineering Program Team  
P O Box 15012  
Colorado Springs, CO 80935-5012

***Prepared for:***

FHWA Office of Operations Research, Development and Technology  
Federal Highway Administration  
Turner-Fairbank Highway Research Center  
6300 Georgetown Pike  
McLean, Virginia 22101-2296

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# Foreword

ITT Industries, Inc., Systems Division is maintaining CORSIM under the direction of the Federal Highway Administration (FHWA) on Contract Number DTFH61-95-C-00125.



# Abstract

This User's Guide describes the input, execution, and output for the CORridor-microscopic SIMulation program (CORSIM). CORSIM is the core simulation and modeling component of the Traffic Software Integrated System (TSIS) tool suite.

This document does not describe the detailed contents of each Record Type (RT) used by CORSIM. The user is referred to the CORSIM Reference Manual for that information. Additionally, this manual does not describe the TSIS environment. The reader is referred to the TSIS User's Guide, and other manuals, guides, and tutorials within the TSIS suite of traffic tools



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# 1 Introduction

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## 1.1 Overview

This User's Guide describes how to prepare the input, analyze the output, and execute the CORSIM simulation and modeling program. Detailed information concerning the input records used by CORSIM can be found in the CORSIM Record Types Reference Manual.

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## 1.2 Simulating Traffic Systems

In traffic engineering, the concept of traffic control is giving way to the broader philosophy of Advanced Traffic Management Systems (ATMS), whose purpose is not only to move vehicles, but also to optimize the utilization of transportation resources to improve the movement of people and goods without impairing the community.

One of the most important analytical tools of traffic engineering is computer simulation. Computer simulation is more practical than a field experiment for the following reasons:

- It is less costly.
- Results are obtained quickly.
- The data generated by simulation include several measures of effectiveness that cannot be easily obtained from field studies.
- The disruption of traffic operations, which often accompanies a field experiment, is completely avoided.
- Many schemes require significant physical changes to the facility, which are not acceptable for experimental purposes.
- Evaluation of the operational impact of future traffic demand must be conducted by using simulation or an equivalent analytical tool.
- Many variables can be held constant.

If a traffic system is simulated on a computer by means of a simulation model, it is possible to predict the effect of traffic control and ATMS strategies on the system's operational performance, as expressed in terms of measures of effectiveness (MOEs), which include average vehicle speed, vehicle stops, delays, vehicle-hours of travel, vehicle-miles of travel, fuel consumption, and pollutant emissions. The MOEs provide insight into the effects of the applied strategy on the traffic stream, and they also provide the basis for optimizing that strategy.

The availability of traffic simulation models greatly expands the opportunity for the development of new and innovative ATMS concepts and designs. Planners and engineers are no longer restricted by the lack of a mechanism for testing ideas prior to field demonstration. Furthermore, because these models produce information that allows the designer to identify the weaknesses in concepts and design, they provide the basis for identifying the optimal form of the candidate approach. Finally, because the results generated by the model can form the basis for selecting the most effective candidate among competing concepts and designs, the eventual field implementation will have a high probability of success.

Many ATMS strategies affect the mode and route choice of trip-makers. To test the effect of ATMS schemes on trip patterns, it is necessary to analyze an area that contains a substantial portion of the routes that the trip-makers may follow. There is a need, therefore, for a simulation model that is capable of representing traffic flow in large urban areas containing surface street networks and freeways and that has reasonable computer usage requirements. This concept of a single integrated simulation system that can provide the user with flexibility and ease of use and that can optimize the efficiency of all computations was conceived by the Federal Highway Administration (FHWA) in the mid-1970s. FHWA has since supported a series of projects to implement this design and to develop the software for CORSIM.

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### 1.3 CORSIM theory of operation

CORSIM consists of an integrated set of two microscopic simulation models that represent the entire traffic environment. NETSIM represents traffic on urban streets and FRESIM represents traffic on freeways. Microscopic simulation models represent movements of individual vehicles, which include the influences of driver behavior. The effects of very detailed strategies, such as relocating bus stations or changing parking restrictions, can be studied with such models.

In a multiple-model network, each of the component models of CORSIM simulates a different subnetwork. The interfacing of adjoining subnetworks is accomplished by defining "interface nodes" (as shown in the following figure), which represent points at which vehicles leave one subnetwork and enter another. Nodes of this type are assigned special numbers to distinguish them from other nodes in the network. The terms "entry interface links," which receive traffic from the adjoining subnetworks, and "exit interface links," which carry traffic exiting the subnetwork to adjoining subnetworks, are used to describe links at the boundaries of the subnetworks.

The following figure illustrates a multiple-model network in which a city's central business district is bordered by a freeway. The freeway sections can be modeled with FRESIM, while the urban subnetwork can be modeled with NETSIM. Once the user identifies the appropriate subnetwork representation, all interfacing processes are handled internally by the model by the interface logic.



Vehicles are moved according to car-following logic, in response to traffic control devices, and in response to other demands. For example, buses must service passengers at bus stops (stations); therefore, their movements differ from those of private vehicles. Congestion can result in queues that extend throughout the length of a link and block the upstream intersection, thus impeding traffic flow. In addition, pedestrian traffic can delay turning vehicles at intersections.

CORSIM accumulates data every time step. At the end of each time period the accumulated data is used to produce MOEs. These MOEs can then be used in conjunction with the Highway Capacity Manual (HCM) to estimate the performance of the network.

CORSIM is capable of simulating most of the prevailing freeway geometries, including multiple-lane freeway mainlines, on/off ramps and connectors to other freeways, variations in grade, radius of curvature and super-elevation, lane additions and lane drops and auxiliary lanes, which are used by traffic to begin or end the lane-changing process or to enter or exit the freeway.

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## 1.4 Elements of the Traffic Environment

The traffic environment, which must be specified by the user, consists of the following:

- Topology of the roadway system (in the form of a link-node diagram)
- Geometrics of each roadway component
- Lane channelizations (such as left-turn only and buses only lanes)
- Traffic volumes entering the roadway system
- Turn movements or origin-and-destination data
- Intersection Approach Geometry
- Stop and Yield Signs
- Pre-timed Signal Control
- Actuated Signal Control
- Freeway Ramp Metering Control
- Incidents and Temporary Events
- Traffic Surveillance Systems
- Fleet Components (buses, carpools, cars, and trucks)
- Load Factors (the number of passengers/vehicle)
- Turn Movement Distributions
- Bus Operations (paths, flow volumes, stations, dwell times, and routes)
- HOV Lanes (buses, carpools, or both)
- Queue Discharge Distribution on surface streets
- Lane Changing Parameters
- Variations in Driver Aggressiveness
- Reaction points for upcoming geometric changes on freeways
- Driver behavior that determines the operational performance of vehicles in the system
- Fuel consumption and pollutant emission rates

The physical environment is represented as a network comprised of nodes and unidirectional links. The links generally represent urban streets or freeway sections, and the nodes generally represent urban intersections or points at which a geometric property changes (such as a change in grade or a major midblock traffic generator).

Another important feature of CORSIM is that characteristics that change over time, such as signal timings and traffic volumes, can be represented by dividing the simulation into a sequence of user-specified time periods, during which the traffic flows, the traffic controls, and the geometry are held constant. Therefore, the morning rush hour might be simulated with one time period representing pre-rush hour, a second representing rush-hour timing, and a third representing the post-rush-hour flows. These time periods are further divided into time intervals.

CORSIM also includes a traffic assignment program, which is designed to expand the applicability of traffic simulation modeling to transportation planners. The program internally translates the origin-and-destination data - which is readily available to the planning community - into a form suitable for use by the simulation models.

The traffic assignment model interfaces with the NETSIM component of CORSIM only and uses conventional static traffic assignment techniques, along with user equilibrium and system optimization capabilities. The purpose of including a traffic assignment model in CORSIM is to extend the potential user group for this program to include planners and traffic engineers.

The planner usually has sufficient information available to produce a table of origin-and-destination volumes that represent traffic demands over an area for a specified period of time. For this information to be useful as input in the NETSIM model, it must first be transformed into link-specific turn percentages. The mechanism for performing this transformation is the traffic assignment model.

The interfacing logic is designed to perform data manipulation internally, thus freeing the user to focus attention on providing the origin-and-destination table. This logic will read and check the data and then perform the necessary data organization to provide the traffic assignment program with its data requirements. Subsequently, it will create turn percentages and entry volumes for input into the NETSIM model.

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## 1.5 Calibration Parameters

There are several CORSIM inputs that are known as calibration parameters. These inputs allow users to fine tune CORSIM to match local real-world traffic conditions. These calibration parameters include driver behavior parameters and vehicle performance parameters. The driver behavior parameters for Netsim include queue discharge headway and start-up lost time, distribution of freeflow speed by driver type, mean duration of parking maneuvers, lane change parameters, maximum left and right turning speeds, probability of joining spillback, probability of left turn jumpers and laggors, gap acceptance at stop signs, gap acceptance for left and right turns, pedestrian delays and driver familiarity with their path. The driver behavior parameters for Fresim include mean start-up delay at ramp meters, distribution of freeflow speed by driver type, incident rubbernecking factor, car-following sensitivity factor, lane change gap acceptance parameters, and parameters that affect the number of discretionary lane changes. Vehicle performance calibration parameters for both Netsim and Fresim include speed and acceleration characteristics, fleet distribution and passenger occupancy. Fresim also includes maximum deceleration values.

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## 1.6 Creating a Network and Calibrating CORSIM

The following steps define the basic process for using TSIS for analyzing an existing traffic network.

1. Determine the network geometry.
2. Obtain traffic and signal data.

## Introduction

3. Build a link-node model of the network using TRAFED, ITRAF or a Text Editor.
4. Run the simulation using CORSIM.
5. View the animation in TRAFVU to verify the inputs and confirm vehicle movement and signal operations.
6. Use the TSIS Multi-Run Same Case script to perform multiple CORSIM simulations of the network using different random number seeds.
7. Examine the distribution of relevant MOEs and compare with field data.
8. Adjust calibration parameters as needed to match field data as closely as possible.
9. Go back to step 7 and repeat the process until CORSIM results and field data match reasonably well.

After performing these steps CORSIM should be properly calibrated for that specific network and can be used to perform other analyses with modifications of the existing network, such as determining the impact of geometry changes. The resulting set of calibration parameters should also be usable for other simulations in which driver behavior and vehicle performance characteristics would be similar.

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## 1.7 CORSIM Capabilities and Limitations

The following tables list many elements of modern traffic systems. CORSIM can model most of those elements explicitly. Many of the other features can be approximated using the basic elements of CORSIM, along with engineering judgement and creativity. The tables are arranged into Freeway and Surface Street systems and show CORSIM capabilities and the types of input data that CORSIM uses to model those systems.

### Freeway Modeling Capabilities

| Modeling Capabilities                         |     |
|---|-----|
| Bottlenecks                                   | Yes |
| HOV lanes, including ramp meter bypass        | Yes |
| Barriers                                      | Yes |
| Lane closures                                 | Yes |
| Interchanges                                  | Yes |
| Weaving sections                              | Yes |
| Toll booths / weigh stations / draw bridges   | No* |
| Oversaturation                                | Yes |
| Time-varying demand                           | Yes |
| Trucks biased or restricted to specific lanes | Yes |
| Incidents                                     | Yes |
| Workzones                                     | Yes |
| Surveillance                                  | Yes |
| Fixed-time ramp metering                      | Yes |
| Time varying fixed-time ramp metering         | Yes |
| Traffic-responsive ramp metering              | Yes |
| Bus operations                                | Yes |

\* These features are not modeled explicitly by CORSIM, but can be modeled using basic CORSIM elements. Some of them require using both surface street elements and freeway elements.

### Freeway Input Data

| <b>Input Data</b>                   |     |
|-------------------------------------|-----|
| Node coordinates                    | Yes |
| Link length                         | Yes |
| Grade                               | Yes |
| Number of lanes                     | Yes |
| Number and type of auxiliary lanes  | Yes |
| Capacity                            | No  |
| Freeflow speed                      | Yes |
| Turn percentages                    | Yes |
| Turn percentages by vehicle type    | Yes |
| Time-varying turn percentages       | Yes |
| Traffic composition                 | Yes |
| Vehicle occupancy                   | Yes |
| O-D table                           | Yes |
| Surveillance detectors              | Yes |
| Fixed-time metering headway         | Yes |
| Traffic-responsive metering inputs  | Yes |
| Number of vehicles per green        | Yes |
| User-defined driver characteristics | Yes |

### Surface Street Modeling Capabilities

| <b>Modeling Capabilities</b> |     |
|------------------------------|-----|
| Bottlenecks                  | Yes |
| Complex intersections        | Yes |
| HOV lanes                    | Yes |
| On-street parking            | Yes |
| Two-way left turn lanes      | No* |
| Oversaturation               | Yes |
| Time-varying demand          | Yes |
| Incidents                    | Yes |
| Pedestrians                  | Yes |
| Workzones                    | Yes |
| Unsignalized intersections   | Yes |
| All-way stops                | Yes |
| Roundabouts                  | No* |
| Fixed-time signals           | Yes |
| Actuated signals             | Yes |

## Introduction

| <b>Modeling Capabilities</b> |     |
|------------------------------|-----|
| Signal coordination          | Yes |
| Surveillance                 | Yes |
| U-turns                      | No* |
| Transit signal priority      | No  |
| Bus operations               | Yes |
| Light rail                   | No* |

\* These features are not modeled explicitly by CORSIM, but can be modeled using basic CORSIM elements. Some of them require using both surface street elements and freeway elements.

## Surface Street Input Data

| <b>Input Data</b>                   |     |
|-------------------------------------|-----|
| Node coordinates                    | Yes |
| Link length                         | Yes |
| Grade                               | Yes |
| Number of lanes                     | Yes |
| Lane channelization                 | Yes |
| Turn pockets                        | Yes |
| Pedestrian traffic                  | Yes |
| Freeflow speed                      | Yes |
| Turn percentages                    | Yes |
| Time-varying turn percentages       | Yes |
| Traffic composition                 | Yes |
| Vehicle occupancy                   | Yes |
| O-D table                           | Yes |
| Signal timing plan                  | Yes |
| Surveillance detectors              | Yes |
| Single ring actuated control        | Yes |
| Dual ring actuated control          | Yes |
| User-defined driver characteristics | Yes |



# 2 Input and Output Details

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## 2.1 Input Data

Computer simulations use a mathematical representation of the real world. Traffic simulation models are representations of the time-varying processes in traffic flow, and they require accurate descriptions of the characteristics of the vehicles, the transportation network, and the traffic control system. These characteristics vary over the physical network and over time. The structure of the input stream must also reflect the concept of network partitioning.

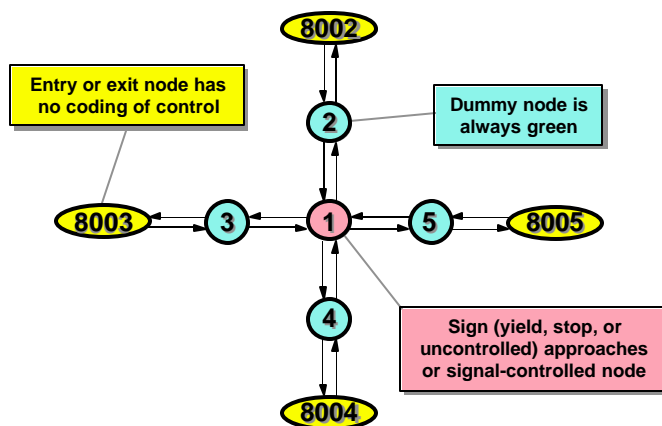
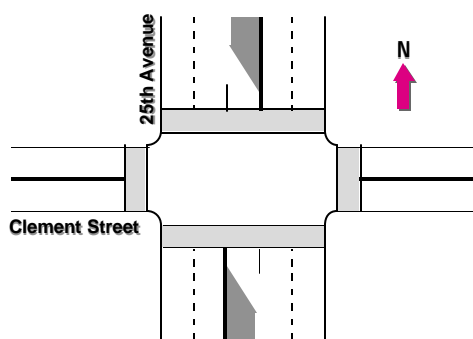
The characteristics that vary over time include the following:

- Traffic volumes
- Turn movements
- Traffic regulations
- Signal timing.

The characteristics that vary over space include the following:

- Traffic geometry (location of links and nodes, number of lanes, turning pockets, and auxiliary lanes)
- Types of links (such as surface streets or freeways)

Links are one-directional segments of surface streets or freeways, and nodes are usually the intersection of two or more links. Initially, the user must obtain geometric pictures of the network, such as aerial photographs or maps. A basic drawing of the geometry of a single intersection is shown in the following figure.

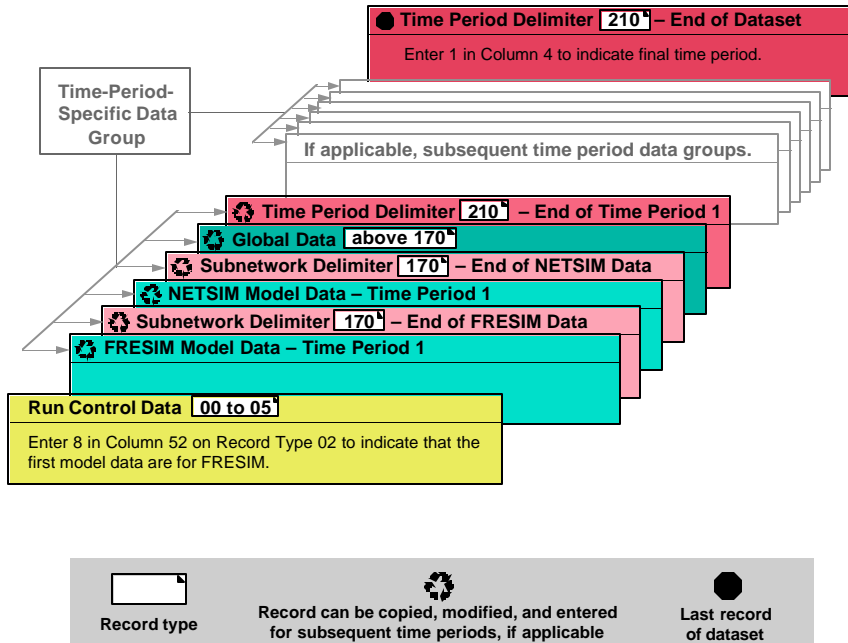


### Intersection layout converted to a link-node diagram

The time-varying portion of the simulation analysis is expressed as a sequence of "time periods" specified by the user; that is, the input data specified by the user for a certain time period remains in force unless changed in a subsequent time period. The user can specify up to 19 time periods and must specify the conditions that have changed during each period. Therefore, the input stream consists of a sequence of "blocks" of data records, with each block defining the conditions that apply to one time period.

Each block of data records for a time period is subdivided into "sections" of data records. Some sections define conditions of one or more subnetworks, including a NETSIM subnetwork and/or a FRESIM subnetwork, while others provide inputs for the specifications that must be specified for the "global" network (such as bus routes).

The input stream of a dataset begins with a basic description of the run being made (run control data), followed by data that is divided into time periods. Each time period contains model-specific data for each subnetwork that is being simulated. Each dataset is divided into a series of 80-column records. The first time period is unique because it contains the data that does not vary from time period to time period. At the end of the model data for the first time period is global network data that is applied to all subnetwork data. This global data describes bus operations, and any other data that applies to both subnetworks. For second and subsequent time periods, only variations in data relative to the previous time periods need to be specified.



**CORSIM data structure**

The following tables list the record types that can be used by each model. The run control data is independent of the model that is being executed and is required for all models. Only one set of run control data records is permitted, even if more than one model and/or time period will be simulated.

**Run control data required to set-up CORSIM simulation runs**

| RECORD TYPE | DESCRIPTION                                  | NETSIM   | FRESIM   |
|-------------|--|----------|----------|
| 00          | Run Title                                    | Optional | Optional |
| 01          | Run Identification                           | Required | Required |
| 02          | Run Control                                  | Required | Required |
| 03          | Time Period Specification                    | Required | Required |
| 04          | Time Interval and Time Steps per Time Period | Required | Required |
| 05          | Reports                                      | Required | Required |

The following table indicates whether each of the remaining record types, beyond the Run Control records identified in the previous section, is required or optional. Blank boxes indicate the specified record type is not applicable to that subnetwork (FRESIM or NETSIM).

## Input and Output Details

### CORSIM record types

| RECORD TYPE | DESCRIPTION   | NETSIM        |                     | FRESIM        |                     |
|-------------|---|---------------|---------------------|---------------|---------------------|
|             |   | Time Period 1 | Time Periods 2 - 19 | Time Period 1 | Time Periods 2 - 19 |
| 10          | Link Names  | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 11          | NETSIM Link Description (NETSIM only)   | Required      | Optional            |               |                     |
| 14          | Lane Alignments (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 19          | Freeway Link Geometry (FRESIM only)   |               |                     | Required      | Not Allowed         |
| 20          | Freeway Link Operation (FRESIM only)  |               |                     | Required      | Not Allowed         |
| 21          | Surface Street Turn Movements (NETSIM only)   | Optional      | Optional            |               |                     |
| 22          | Conditional Turn Movements (NETSIM only)  | Optional      | Optional            |               |                     |
| 23          | Turn Movement Variations within a Time Period (NETSIM only)   | Optional      | Optional            |               |                     |
| 24          | Vehicle Type Specific Multipliers for Freeway Turn Movements (FRESIM) or for Surface Street Turn Movements (NETSIM) | Optional      | Optional            | Optional      | Optional            |
| 25          | Freeway Turn Movements (FRESIM only)  |               |                     | Required      | Optional            |
| 26          | Turn Movement Variations within a Time Period (FRESIM only)   |               |                     | Optional      | Optional            |
| 28          | Surveillance Specification (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 29          | Freeway Incident Specification (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 32          | Freeway Lane Add and/or Drop (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 33          | HOV Specific Input (FRESIM only)  |               |                     | Optional      | Optional            |
| 35          | Sign or Pre-timed Signal Control Timing (NETSIM only)   | Optional      | Optional            |               |                     |
| 36          | Sign or Pre-timed Signal Control Codes (NETSIM only)  | Optional      | Optional            |               |                     |
| 37          | Freeway Metering (FRESIM only)  |               |                     | Optional      | Optional            |
| 38          | Freeway Metering Detector Specification (FRESIM only)   |               |                     | Optional      | Not Allowed         |
| 42          | Surveillance Specification (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 43          | Approach Configuration for Actuated Controller (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 44          | Coordination for Actuated Controller (NETSIM only)  | Optional      | Not Allowed         |               |                     |

| RECORD TYPE | DESCRIPTION   | NETSIM        |                     | FRESIM        |                     |
|-------------|---|---------------|---------------------|---------------|---------------------|
|             |   | Time Period 1 | Time Periods 2 - 19 | Time Period 1 | Time Periods 2 - 19 |
| 45          | Traffic Movements for Actuated Controller (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 46          | Detectors for Actuated Controller (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 47          | Phase Operations for Actuated Controller (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 48          | Pedestrian Operations for Actuated Controller (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 50          | Entry Link Volumes  | Optional      | Optional            | Optional      | Optional            |
| 51          | Traffic Volumes on Source/Sink Links (NETSIM only)  | Optional      | Optional            |               |                     |
| 52          | Load Factors (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 53          | Entry Link Volume Variations within a Time Period   | Optional      | Optional            | Optional      | Optional            |
| 54          | Short-term Events (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 55          | Long-term Events (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 56          | Parking Activity (NETSIM only)  | Optional      | Optional            |               |                     |
| 58          | Vehicle Type Specifications (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 61          | On-line Incident Detection Specifications (FRESIM only)   |               |                     | Optional      | Not Allowed         |
| 62          | On-line Incident Detection Algorithm Parameters (FRESIM only)   |               |                     | Optional      | Not Allowed         |
| 63          | On-line Incident Detection Detector Station Identification (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 64          | Off-line Incident Detection, Point Processing, or MOE Estimation Specification (FRESIM) or Evaluation Frequency for Surveillance Detectors (NETSIM) | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 65          | Off-line Incident Detection Algorithm Parameters (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 66          | MOE Algorithm Parameters (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 67          | Off-line Incident Detection, Point Processing, or MOE Estimation Detector Station (FRESIM only)   |               |                     | Optional      | Not Allowed         |
| 68          | Car-Following Sensitivity Factor (FRESIM only)  |               |                     | Optional      | Not Allowed         |
| 69          | Pavement Friction Coefficients-Lag to Accelerate and Decelerate (FRESIM only)   |               |                     | Optional      | Not Allowed         |

## Input and Output Details

| RECORD TYPE | DESCRIPTION   | NETSIM        |                     | FRESIM        |                     |
|-------------|---|---------------|---------------------|---------------|---------------------|
|             |   | Time Period 1 | Time Periods 2 - 19 | Time Period 1 | Time Periods 2 - 19 |
| 70          | Lane Change Parameters, Minimum Separation for Vehicle Generation, and Maximum Non-Emergency Deceleration (FRESIM only) |               |                     | Optional      | Not Allowed         |
| 71          | Vehicle Type Specifications (FRESIM only)   |               |                     | Optional      | Not Allowed         |
| 74          | Origin-Destination (FRESIM only)  |               |                     | Optional      | Optional            |
| 80          | Optional Link Geometric Data (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 81          | Lane-Change Parameters (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 90          | Link Aggregations (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 95          | Interchange Definition Data (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 96          | Interchange Origin Destination Data (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 140         | Left-Turn Jump, Left- and Right-Turning Speeds (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 141         | Spill-back Probability and Probability of Left-Turn Lagger (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 142         | Acceptable Gap in Near-Side Cross Traffic for Vehicles at a Sign (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 143         | Additional Time for Far-Side Cross Traffic in Acceptable Gap for Vehicles at a Sign (NETSIM only)                       | Optional      | Not Allowed         |               |                     |
| 144         | Amber Interval Response (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 145         | Gaps for Permissive Left-Turns and for Right-Turns on Red or at Signs (NETSIM only)                                     | Optional      | Not Allowed         |               |                     |
| 146         | Pedestrian Delay (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 147         | Free-Flow Speed Percentages (NETSIM only)   | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 148         | Short-Term-Event Duration Percentages (NETSIM only)   | Optional      | Not Allowed         |               |                     |
| 149         | Link Type Distributions (Queue Discharge Headways and Start-Up Lost Time) (NETSIM only)                                 | Optional      | Not Allowed         |               |                     |
| 150         | Dwell Time Distributions (NETSIM only)  | Optional      | Not Allowed         |               |                     |
| 152         | Distribution of Longitudinal Distance to Start to Attempt a Lane Change (NETSIM only)                                   | Optional      | Not Allowed         |               |                     |
| 153         | Driver's Familiarity with Paths Distribution (NETSIM only)  | Optional      | Not Allowed         |               |                     |

| RECORD TYPE | DESCRIPTION                                 | NETSIM        |                     | FRESIM        |                     |
|-------------|---|---------------|---------------------|---------------|---------------------|
|             |   | Time Period 1 | Time Periods 2 - 19 | Time Period 1 | Time Periods 2 - 19 |
| 170         | Sub-network Delimiter                       | Required      | Required            | Required      | Required            |
| 172         | Environmental Tables                        | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 173         | Maximum Acceleration Tables                 | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 175         | Traffic Assignment Parameters (NETSIM only) | Optional      | Not Allowed         |               |                     |
| 176         | Origin Destination Trip Table (NETSIM only) | Optional      | Not Allowed         |               |                     |
| 177         | Source/Sink Nodes (NETSIM only)             | Optional      | Not Allowed         |               |                     |
| 185         | Bus Stations (NETSIM only)                  | Optional      | Not Allowed         |               |                     |
| 186         | Mean Dwell Time for Buses (NETSIM only)     | Optional      | Optional            |               |                     |
| 187         | Bus Route Definition                        | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 188         | Bus Route Station Stops (NETSIM only)       | Optional      | Not Allowed         |               |                     |
| 189         | Bus Headways (Flow Rates)                   | Optional      | Optional            | Optional      | Not Allowed         |
| 195         | Node Coordinate Data                        | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 196         | Optional Link Geometric Data                | Optional      | Not Allowed         | Optional      | Not Allowed         |
| 210         | Time Period Delimiter                       | Required      | Required            | Required      | Required            |

The following table describes the required record types in FRESIM for point processing, on-line and off-line incident detection (ID), and MOE estimation.

**Required record types in FRESIM for point processing, on-line and off-line incident detection, and MOE estimation**

| RECORD TYPE                | POINT PROCESSING | ON-LINE INCIDENT DETECTION  | OFF-LINE INCIDENT DETECTION | MOE ESTIMATION |
|----------------------------|------------------|---|-----------------------------|----------------|
| 02<br>ENTRY 2<br>(ID FLAG) | <b>ON</b>        | <b>ON</b> FOR<br>POINT-<br>PROCESSING-<br>BASED ID<br><br><b>OFF</b> FOR<br>STANDARD ID | <b>ON</b>                   | <b>ON</b>      |
| 28                         | Required         | Required  | Required                    | Required       |
| 61                         |                  | Required  |                             |                |
| 62                         |                  | Required  |                             |                |
| 63                         |                  | Required  |                             |                |
| 64                         | Required         |   | Required                    | Required       |
| 65                         |                  |   | Required                    |                |
| 66                         |                  |   |                             | Required       |

## Input and Output Details

| RECORD TYPE | POINT PROCESSING | ON-LINE INCIDENT DETECTION | OFF-LINE INCIDENT DETECTION | MOE ESTIMATION |
|-------------|------------------|----------------------------|-----------------------------|----------------|
| 67          | Required         |                            | Required                    | Required       |

The input ("trf") file, consisting of Record Types 00 through 210 as specified in this manual, should be regarded as providing fixed format input. This means that, generally, blanks are treated as zeros. Therefore, data should be entered right justified unless otherwise directed in the specific Record Type documentation. If a data field is 2 columns wide, a 2 followed by a blank will most likely be read as 20.

CORSIM datasets can be coded with very few record types. Assuming that traffic assignment is not executed, the minimum records that are required to run NETSIM and FRESIM are shown in the proper sequence in the following table for a single time period dataset.

### Minimum coding requirements for the CORSIM models

| RECORD TYPE | DESCRIPTION  | NETSIM   | FRESIM   |
|-------------|--|----------|----------|
| 01          | Run Identification   | Required | Required |
| 02          | Run Control  | Required | Required |
| 03          | Time Period Specification  | Required | Required |
| 04          | Time Interval and Time Steps per Time Period                       | Required | Required |
| 05          | Reports  | Required | Required |
| 11          | NETSIM Link Description (NETSIM only)                              | Required |          |
| 19          | Freeway Link Geometry (FRESIM only)                                |          | Required |
| 20          | Freeway Link Operation (FRESIM only)                               |          | Required |
| 21          | Surface Street Turn Movements (NETSIM only)                        | Required |          |
| 25          | Freeway Turn Movements (FRESIM only)                               |          | Required |
| 35          | Sign or Pre-timed Signal Control Timing (NETSIM only)              | Required |          |
| 36          | Sign or Pre-timed Signal Control Codes (NETSIM only)               | Required |          |
| 50<br>53    | Either 50 or 53, or both, can be used to define Entry Link Volumes | Required | Required |
| 170         | Sub-network Delimiter  | Required | Required |
| 210         | Time Period Delimiter  | Required | Required |

Some of the characteristics associated with a network are limited to a maximum size, whose limits are summarized in the following table.

### Size limitations of CORSIM network characteristics

| CHARACTERISTIC       | NETSIM         | FRESIM         |
|----------------------|----------------|----------------|
| Actuated Controllers | 100            | Not Applicable |
| Auxiliary Lanes      | Not Applicable | 3              |
| Bus Routes           | 100            |                |



| CHARACTERISTIC  | NETSIM         | FRESIM         |
|---|----------------|----------------|
| Bus Stations  | 99             | Not Applicable |
| Buses   | 256            | 200            |
| Data Stations   | Not Applicable | 200            |
| Detector Stations   | Not Applicable | 200            |
| Detectors   | 300            | 600            |
| Detectors for a Metering Signal   | Not Applicable | 10             |
| Disjoint Freeway Segments   | Not Applicable | 20             |
| Entries per Segment   | Not Applicable | 35             |
| Events  | 200            | Not Applicable |
| Exits per Segment   | Not Applicable | 35             |
| Incidents   | Not Applicable | 20             |
| Lane Adds/Drops per Link  | Not Applicable | 3              |
| Links   | 1000           | 1000           |
| Links per Segment   | Not Applicable | 200            |
| Nodes   | 500            | 500            |
| Ramp Metering Signals   | Not Applicable | 150            |
| Sections of Aggregated Links  | 100            | Not Applicable |
| Through Lanes   | 7              | 5              |
| Through Lanes per Ramp Link   | Not Applicable | 3              |
| Vehicles*   | 20,000         | 20,000         |
| *This is the limit on the number of vehicles that can be simulated in a time step. However, an unlimited number of vehicles can be processed during the length of the simulation. |                |                |

## 2.2 Data Record Types

This section provides an overview of the various blocks of data records that are used to input data in CORSIM.

### 2.2.1 Run Control Data

Run control data consists of six record types:

1. Record Type 00 provides the title for the run.
2. Record Type 01 provides the name of the person performing the run, the date of the run, the name of the organization involved, and the run identification number.
3. Record Type 02 provides data on whether one or more models are to be run, whether traffic assignment is to be performed, the maximum initialization period to be used, and whether fuel consumption and emissions data should be output. This record also tells CORSIM which model to read input for first and what random number seeds to use.
4. Record Type 03 is the time period specification record that informs CORSIM how many time periods will be simulated as well as the duration of each time period. These time periods are used

to divide the simulation into segments with similar characteristics, such as pre-rush hour, rush hour, and post-rush hour.

5. Record Type 04 specifies the time interval duration, which is used to control the frequency of the output reports provided by CORSIM.
6. Record Type 05 is the final record in the block of run control data records, and it specifies the types of output desired by the user. The frequency of both cumulative and intermediate output is specified.

### 2.2.2 Reports and Output Specifications

Reports and outputs are controlled with several data records. Record Type 03 specifies whether fuel consumption and emissions data should be output. Record Type 05 specifies the frequency of both cumulative and intermediate output. Record Type 90 allows aggregation of links as a group for data collection and reporting purposes for NETSIM and FRESIM. Up to 1,000 links can be contained within a maximum of 100 sections.

### 2.2.3 Link Names

Link names can be specified on Record Type 10 for the CORSIM model. This block of data records appears at the beginning of the data records for Time Period 1 only. Links cannot be renamed in subsequent time periods.

### 2.2.4 Link Description

Networks in CORSIM consist of uni-directional links. In the case of a two-way street, each roadway block would consist of two uni-directional links. Links are defined by their upstream and downstream node numbers as shown in the following figures. Entry links, exit links, interface links, and internal links have different kinds of node numbering.

The eastbound link is link (I, J) and has an upstream node number of I and a downstream node number of J. The westbound link is link (J, I) and goes from upstream node J to downstream node I.

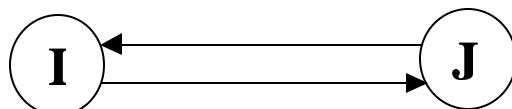


Diagram of a NETSIM link

The eastbound link is link (I, J) and has an upstream node number of I and a downstream node number of J. A corresponding westbound link for a freeway must be specified by a unique pair of upstream node and downstream node, K and L (respectively).

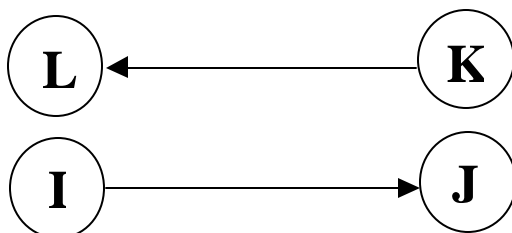


Diagram of a FRESIM link

Entry and/or exit nodes must be numbered between 8000 and 8999. Therefore, entry links have an upstream node number in the 8000's. Interface nodes which are used to join NETSIM and FRESIM sub-networks, must

be numbered between 7000 and 7999 so interface links have either an upstream or downstream node in the 7000s. Internal nodes can be numbered from 1 to 1000. Internal links must have both upstream and downstream nodes numbered less than 1000.

The geometrics for each NETSIM link are coded on Record Type 11. Link records describe the number of lanes and their length, channelization (left turn only or buses only), and link-specific traffic behavior (such as free-flow speed). The link geometrics and operation data for FRESIM are coded on Record Types 19 and 20, respectively.

Turn movement descriptions describe how traffic leaves each link to approach other links. Turn movements for NETSIM are described on Record Type 21. Record Type 22 can be used to define conditional turn movements in NETSIM. Record Type 23 is used to specify time-varying turn movements within a time period for NETSIM. Record Types 25 and 26 are used to specify uniform and time-varying turn movements for FRESIM, respectively.

## 2.2.5 Traffic Parameters

Traffic parameters provide CORSIM with a description of how traffic behaves, and they can be specified by a variety of record types. These parameters are input into the data file in Time Period 1 only. Therefore, they remain in effect throughout the entire simulation time. Examples of traffic parameters include the response to gaps in traffic for turning vehicles, the distribution of the desired free-flow speed, and vehicle types.

For NETSIM, Record Types 140 and 141 modify the turn calibration data and spill-back, while Record Types 142 and 143 modify the acceptable gaps for turning vehicles pulling out onto a main street at stop signs. Record Type 144 describes vehicle response to yellow signals. Gaps in oncoming traffic that are acceptable for vehicles turning onto a side street across traffic are described on Record Type 145. Record Type 146 describes how pedestrian flows interact and impede traffic. Variation of free-flow speed around the user-specified free-flow speed is modified by Record Type 147. Short-term events vary according to a distribution that may be modified by Record Type 148. Start-up lost time and queue discharge headway at traffic signals vary according to distributions that may be changed by Record Type 149. The length of time that buses "dwell" at bus stops varies according to distributions that are modified by Record Type 150.

For FRESIM, Record Type 68 modifies the embedded car-following sensitivity factors, while Record Type 69 modifies the lag to accelerate and decelerate when drivers are making required maneuvers. Record Type 70 allows users to change the minimum separation for vehicle generation and lane-changing parameters, such as the time to complete a lane change, the percentage of cooperative drivers, and non-emergency deceleration. Variation of free-flow speed around the user-specified free-flow speed is modified by Record Type 147.

## 2.2.6 Bus Operations

Bus operations in a network are described in terms of bus routes, stations, and flow rates. Each route is assigned a "route number," which is then used to identify the flow rates, release offsets, and stations that buses may stop at along the route. The bus route is the geometric path of nodes that the bus traverses as it travels through the network. The bus flow rate is the mean headway for buses that service a particular route number. The bus stations are defined in terms of the link they are on, the distance from the downstream node, and their capacity (in numbers of buses). The average dwell time buses spend at stations is also specified.

Buses operate at a fixed headway in CORSIM. Bus stops are defined on Record Type 185. The average time each bus stops (dwells) at a station, along with the percentage of buses that do not stop, is defined on Record Type 186 (see also Record Type 150 for dwell time distributions). The route of each bus traveling through the network is defined by the series of nodes it traverses, including bus stops. The nodes are defined on Record Type 187, while the bus stops on each route are defined on Record Type 188. The routes can traverse the interface nodes between sub-networks so that a route may cover NETSIM and FRESIM streets and highways. However, bus stops cannot be specified on a FRESIM link.

CORSIM computes measures of effectiveness for buses on a route-specific basis. The delays and stops for buses are also included in the overall MOEs computed by CORSIM.

## **2.2.7 HOV Lane Operations**

In NETSIM lanes can be channelized for buses only, carpools only, or buses and carpools only using Record Type 11. In FRESIM HOV lanes can be defined using Record Type 33.

## **2.2.8 Sign and Signal Control**

Stop and yield signs (which are available in NETSIM) are specified on Record Types 35 and 36. Record Type 35 defines the upstream node of each approach to the intersection, while Record Type 36 defines whether the approach is controlled by a yield sign or stop sign or is uncontrolled (i.e., perpetual green). The model cannot simulate all four-way stops.

Pre-timed signals are also specified on Record Types 35 and 36. Record Type 35 defines the upstream node of each approach to the intersection, the number of signal intervals, and the duration of each interval. Record Type 36 defines the control facing each approach during each interval, such as green ball, amber ball, red ball, green left turn arrow, etc. Signal transition from one timing plan to another is available for pre-timed signals in NETSIM, but is not available for actuated signals. Pre-timed signals may transition over one, two, or three cycles as defined in Entry 16 on Record Type 02.

For actuated control in NETSIM, Record Type 43 defines the approaches and referenced links. Actuated coordination in NETSIM is controlled by Record Type 44, which defines the time when permissive periods begin and end and when force-offs occur. Record Type 45 defines the traffic movements that are permitted during each phase, which are defined in terms of left, through, right, and diagonal, rather than in terms of signal indications. Record Type 46 defines detector characteristics, location, and type. Phase operations are described on Record Type 47. Operational characteristics include maximum green time or maximum extension as well as vehicle extension or gap reduction time. Extensions of the phase timing for pedestrians are specified on Record Type 48. Actuated timing plans cannot be modified between time periods and will remain constant for the duration of the simulation run.

For ramp-metering control in FRESIM, Record Type 37 defines four types of on-ramp signal control strategies, and Record Type 38 defines the location of the detectors necessary for the application of metering strategies.

## **2.2.9 Traffic Volumes and Vehicle Occupancy**

Traffic volumes entering from outside the network are defined on Record Type 50. Traffic volumes leaving the network are not defined; they are the result of turn movements onto exit links. Traffic volumes entering or leaving the network from within the network are defined on Record Type 51. They are called source/sink volumes and occur on internal links. They are used to represent the behavior of other traffic sources or attractors, such as parking lots and office locations. Vehicle occupancy (the number of people per vehicle) can be entered on Record Type 52.

## **2.2.10 NETSIM Events and Parking Maneuvers**

NETSIM has both short- and long-term interruptions to traffic (known as "events"). Short-term events are events with an average duration of less than 60 seconds that take place in the curb lane. Record Type 54 is used to specify short-term events. Long-term events are longer-duration interruptions to traffic for any regular (non-pocket) lane. Record Type 55 is used to specify long-term events. Interruptions to traffic by parking maneuvers can also be modeled in NETSIM and are specified on Record Type 56. Parking activity can vary from time period to another, but only on links with parking.

## **2.2.11 Freeway Incidents**

FRESIM uses Record Type 29 to specify freeway incidents - either blockages or rubbernecking - that occur on a lane-specific basis. Each incident occurs at a specified location, extends over a user-specified length of the freeway, and lasts for any desired length of time. FRESIM also allows users to specify both on-line and off-

line incident detection specifications and algorithms with Record Types 61-67. See the *CORSIM data structure* table for the entries required on record types for incident detection in FRESIM.

### 2.2.12 Vehicle Characteristics

NETSIM and FRESIM now use the same vehicle performance characteristics. Record Type 173 is used to specify the maximum acceleration tables used to define vehicle performance for both NETSIM and FRESIM.

### 2.2.13 Fuel consumption and pollutant emissions

Detailed vehicle characteristics for fuel consumption and pollutant emissions can be specified. NETSIM and FRESIM now use the same tables for fuel consumption and emissions. Record Type 172 is used to specify the data tables for both NETSIM and FRESIM. The fuel consumption rates can be specified for autos, trucks, and buses. Only one rate of HC emissions, CO emissions, and NOx emissions can be set for all types of vehicles.

### 2.2.14 Urban Interchanges

Multilevel urban interchanges can be modeled in NETSIM. In previous versions, interchanges could be modeled, but the user was required to enter turn percentages for each link within the interchange. To further assist in the coding of interchanges, an option of entering travel demand patterns (i.e., origin-destination information) through an interchange instead of turn percentages for each link has been added in this version. Information on interchanges is entered on Record Types 95 and 96.

To allow for more realistic representation of interchanges in the graphics the capability of having curved links and grade separations has been added. Information for these options is entered on Record Type 196. Node coordinates are entered on Record Type 195 in feet units.

### 2.2.15 NETSIM Traffic Assignment

Traffic assignment of O-D data is possible for the NETSIM model. Specification of the traffic assignment parameters for FHWA's (BPR's) or Davidson's functions and their related factors is entered on Record Type 175. Specification of the trip table, in the form of origin-and-destination nodes, is entered on Record Type 176. Sources and/or destinations (sinks) of traffic that are internal to the network can be specified on Record Type 177.

When traffic assignment is requested, all record types relating to entry volumes and turn movements should be left out of the dataset; the volumes and percentages will be determined by the traffic assignment results. When using traffic assignment, Record Types 22, 50, and 51 should not appear in the dataset. Entries 7-11 can be used on Record Type 21 to define prohibited turn movements, but Entries 3-6 should be left blank.

Although traffic assignment models are not categorized as simulation models, they represent an essential interface between travel demand and actual traffic flows. Assignment models can serve two purposes: to convert O-D trip tables into actual network loadings for processing by simulation models and to evaluate demand responses to operational changes.

Two optimization techniques are used in the traffic assignment model: the user equilibrium assignment and the system optimal assignment. The criterion for determining when user equilibrium has been reached is that no driver can reduce his journey time (or impedance) by choosing a new route. The criterion for the system optimization is the minimum total cost of the entire network.

A given origin-destination demand matrix is assigned over the specified network. The results of the traffic assignment are then transformed into link-specific turn percentages as required by the simulation models, which commence operation following the assignment process.

The impedance function employed by the traffic assignment model is the FHWA formula and modified Davidson's queuing functions that relate link travel time to link volume and link characteristics (capacity and free-flow travel time). Traffic assignment is performed on a transformed path network that represents the

specified turn movements in the original network. The algorithm that is used is a Frank-Wolfe decomposition variation that generates all-or-nothing traffic assignments at each iteration using the link impedances produced by the previous iteration.

For each iteration, a minimum path tree is constructed for each specified origin node to all other network nodes, using a label-correcting algorithm. The network cost function is evaluated at the end of each iteration, and a line search is conducted for the improved link flows that minimize the cost function. The iterative procedure terminates when convergence is attained or when a pre-specified upper bound on the number of iterations is reached.

### 2.2.16 FRESIM Traffic Assignment

The traffic volume data in FRESIM are organized into the entrance volume (Node 8XXX) (in record type 50) and the percentage of turning volume at ramp exits (in record type 25). A gravity model was implemented in FRESIM to calibrate the turning percentages to an Origin Destination (OD) table in percentages.

First of all, the destination volumes are modeled by linear systems according to the data from record type 50 and record type 25. The Jacobi Method is used to iteratively solve the linear systems. Where there are groups of freeway interchanges, in some rare cases, the sufficient condition for the convergence of the linear systems can not be satisfied. Consequently, the destination volumes **MAY** not converge (We have not found any such case in our tests). If that happens, a warning message will be given to the user.

Secondly, record type 74 is designated to specify an OD pair in percentage from an origin node to a destination node. The user is responsible for ensuring that the traffic volumes for all destination nodes agree with the traffic volume calibrated in the first step using record type 25 and record type 50. Otherwise, the OD table may not be balanced. If that happens, a warning message will indicate the unbalanced volumes at specific exit nodes. The user should make the desirable change.

If the convergence could not be achieved and/or the OD table could not be balanced, CORSIM can still run. However, CORSIM can not assign the correct volumes on all links. CORSIM will report the OD tables to assist the user in debugging the OD input data.

Please refer to record type 25, record type 50 and record type 74 discussions for details.

### 2.2.17 Graphics

Detailed graphical outputs are available in CORSIM. To obtain these outputs, the locations of all nodes must be specified relative to each other. Record Type 195 specifies the x and y coordinates of each node. To depict the links more realistically, their shape as well as their length must be specified. Record Type 196 provides link geometric data that describes link curvature and overpass/underpass relationships.

### 2.2.18 Data Delimiters

Record Type 170 and Record Type 210 are used to separate input data for sub-networks and time periods, respectively. Within a time period, data for each subnetwork is separated by a Record Type 170. Each time period ends with a Record Type 210, which indicates whether it is followed by additional time period data or is the last data record in the input stream.

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## 2.3 Input Diagnostics

CORSIM contains a thorough set of diagnostic tests for input, which are executed in the following sequence:

- Test that the structure of the input stream is correct, that all records are in proper sequence, and that no required records have been omitted.
- Test that each data item is valid and that its value lies within a "reasonable" range.

- Test that the set of data items on a record is internally consistent, with no missing items.
- Test that all the data items on the set of records belonging to one record type are consistent and that the set is complete.
- Test that the data on all record types of a particular classification are compatible and that the classification is completely defined. A classification describes an attribute of the traffic environment, such as network geometry, traffic operations, intersection control, and traffic demand. All the record types belonging to a classification are grouped together.
- Test that the data items of all classifications are compatible and completely define the network.

Whenever an error is detected in the tests outlined above, an error message is generated. Each message contains sufficient information to allow the user to identify the cause and make any required changes.

Two categories of messages are identified: "warning messages" and "fatal error messages." Warning messages identify unusual conditions that may or may not represent an error in the input data. Conditions that lead to warning messages will not prevent the simulation from running, but they may lead to an incorrect result. The legitimacy of such conditions should always be verified by the user. Fatal error messages identify conditions that will prevent the simulation from running.

Because of data interactions and the complexity of the diagnostic tests, the presence of a single error can generate a large number of messages. An effort has been made to restrict extensive output that reports numerous inconsistencies stemming from a single error. Therefore, several diagnostic tests are not performed until entire sections of the data are error free. For example, the logic checks that the geometric and traffic control specifications provide a means to discharge all traffic that might enter each link. On an urban subnetwork, this requires consistency among several different types of data:

- Turn movement data must identify the expected discharging movements from each link (Record Type 21).
- Geometric specifications must identify a receiving link for traffic executing each of these discharge movements (Record Type 11).
- Traffic control specifications for the link must provide some opportunity (sign or signal phase) to service traffic for each of these turn movements (Record Types 35 and 36 for pretimed controllers and Record Types 43-48 for actuated controllers).

Because of similar data interactions, many tests on traffic assignment data and bus transit operations are not performed until much of the data is error free.

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## 2.4 CORSIM Output

CORSIM include four main sections: input data echo, initialization results, intermediate results, and end of time period results. The intermediate results and end of time period results include separate output sections for NETSIM and FRESIM subnetworks. NETSIM also includes an output section that is time period specific. All other output is cumulative since the beginning of the simulation.

The input data echo consists of a copy of the input file and tables stating the complete specification of the traffic environment and run options, including all the user-supplied inputs and default values. They can be used for checking the validity and acceptability of values and parameters.

The initialization statistics show how the vehicles filled the network at different time intervals prior to the network reaching equilibrium. The initialization results are not included in the cumulative results. CORSIM starts accumulating statistics after equilibrium has been reached.

Intermediate results are optionally printed out at the end of user specified intervals. Intermediate and end of time period results include measures of effectiveness (MOE) that are used to evaluate traffic systems.

## 2.4.1 NETSIM MOEs

### 2.4.1.1 Netsim Link MOEs

The following are the link MOEs:

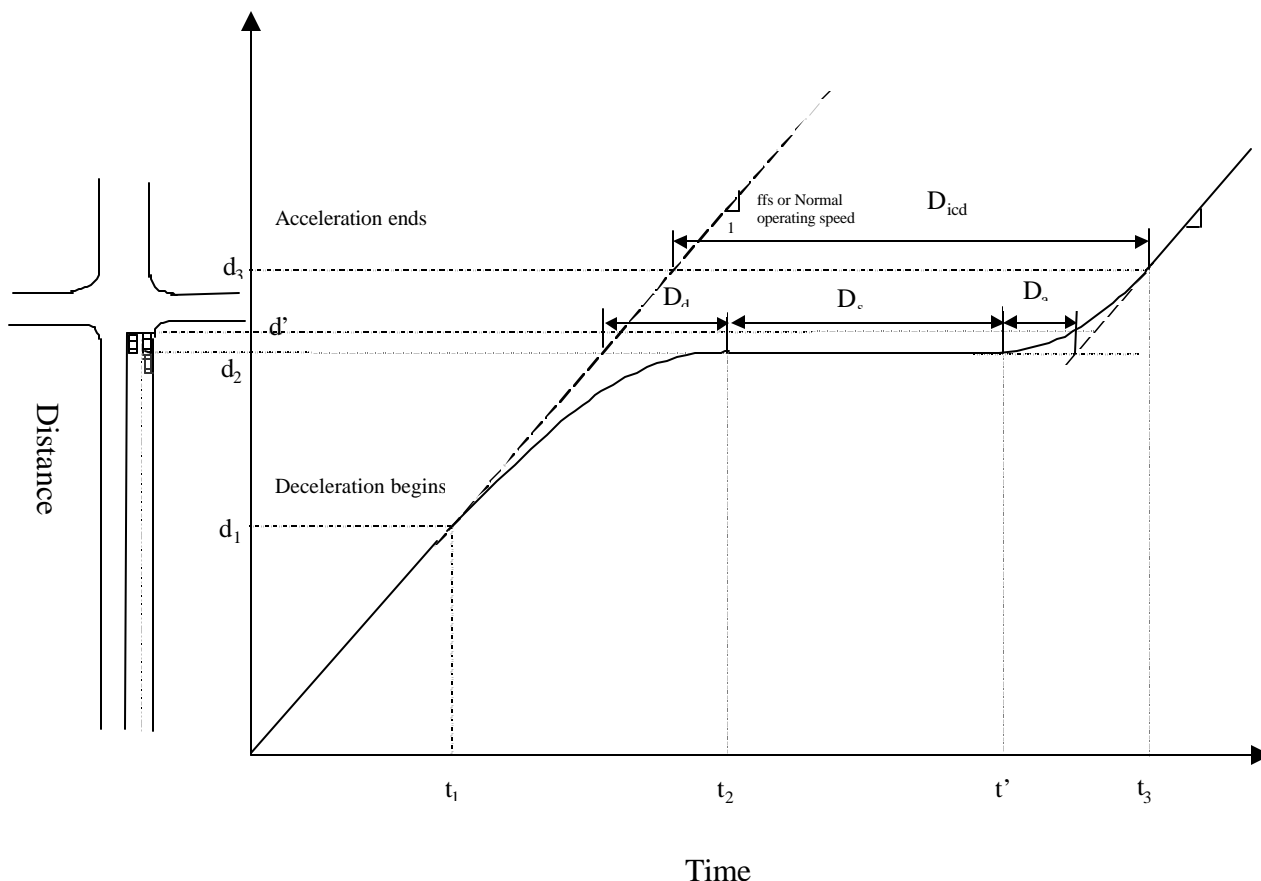
- Vehicle Trips - The number of vehicles that have been discharged from the link since the beginning of the simulation.
- Vehicle Miles - The vehicle trips times the length of link.
- Total Time (veh-min) - Total time on the link for all vehicles.
- Move Time (veh-min) - The theoretical travel time if vehicles are traveling at the free flow speed, calculated by the total travel time multiplied by the ratio of the calculated speed to the free flow speed.
- Delay Time (veh-min) - The difference between the total travel time and the moving time, represents the time that vehicles are delayed if they cannot travel at the free flow speed.
- Total Time (min per mile) - The average actual travel speed on the link, calculated by taking the total travel time and dividing it by the vehicle miles.
- Delay Time (min per mile) - The delay time in veh-min divided by the vehicle miles traveled.
- Total Time per vehicle (sec per veh) - The average travel time on a link for each vehicle, calculated by taking the total travel time and dividing it by the number of vehicle trips.
- Delay Time per vehicle (sec per veh) - The average delay on a link for each vehicle, calculated by taking the delay time in veh-min and dividing it by the number of vehicle trips.
- Queue Delay per vehicle (sec per veh) - Delay calculated by taking vehicles having acceleration rates less than 2 feet per second<sup>2</sup> and speed less than 9 feet per second. If a vehicle's speed is less than 3 feet per second, it will be included every second. Otherwise it will be included every two seconds.
- Control Delay per vehicle (sec per veh) - (see Control Delay)
- Stopped Time per vehicle (sec per veh) - The time the vehicle's speed is less than 3 feet/second on the link and includes the bus dwell time.
- Stop Percentage - The ratio of the number of vehicles that have stopped at least once on a link to the total link trips.
- Average Volume (veh per hr) - Total vehicle trips divided by the simulation time.
- Average Speed (miles per hr) - Total vehicle miles divided by the total travel time.
- Average Occupancy (veh) - The summation of the vehicle content on a link every 5 seconds for the entire simulation run.
- Storage (%) - This is a value calculated by taking a constant (i.e., 6) times the adjusted vehicle length (i.e., a weighted average of all vehicle types on a link) divided by the lane length (i.e., includes the full lanes and turning pockets).
- Phase Failure - The number of times during the simulation that the queue fails to be discharged completely during a green phase.
- Average Queue Length by lane (veh) - The average queue length on a lane since the beginning of the simulation.
- Maximum Queue Length by lane (veh) - The maximum queue length that was observed on a lane since the beginning of the simulation (i.e., 100 percentile).



- Number of Lane Changes - The number of lane changes that occurred on a link during the simulation run.
- Vehicles discharged per lane

### 2.4.1.2 Control Delay

In the 1997 version of HCM, the ICD was defined as the delay incurred by the control facility. “Control delay includes initial deceleration delay, queue move-up time, stopped delay and final acceleration delay”. The following figure illustrates the components of control delay.



It can be seen that

$$D_{icd} = D_d + D_s + D_a \tag{1}$$

where

$D_{icd}$ : Intersection control delay

$D_s$ : Stopped delay

$D_d$ : Delay incurred while a vehicle is decelerating while approaching the stop bar or the end of the queue

$D_a$ : Delay incurred while a vehicle is accelerating to gain its full operating speed after the signal indication turns green

The intersection control delay  $D_{icd}$  can be calculated as follows:

## Input and Output Details

$$D_{icd} = (t_3 - t_1) - \frac{d_3 - d_1}{V} \quad (2)$$

Where  $V$  is the normal operating speed of the vehicle before the vehicle slows down and responds to intersection control. When traffic volume is light, the free flow speed (ffs) of the vehicle on the link can replace  $V$  in equation (2). However, at high demand,  $V$  can be considerably smaller than ffs. In other words, while the vehicle is delayed by intersection control, it is also delayed by high volume. The total delay from time  $t_1$  to  $t_3$  is calculated in equation (3).

$$D_{total} = D_{icd} + \left( \frac{d_3 - d_1}{V} - \frac{d_3 - d_1}{ffs} \right) \quad (3)$$

It should be pointed out that only control delay fully accounts for any slow down caused by intersection signal control. Stopped delay ( $D_s$ ) only considers the time lost while a vehicle stops in the queue waiting for a green signal indication or waiting for its leader to move forward. It does not consider the time lost while the vehicle is slowing down and approaching the stop bar or the end of the queue ( $D_d$ ), nor it considers the time lost while a vehicle is in a process of regaining its normal operating speed ( $D_a$ ). Approach delay may fully accounts for  $D_s$  and  $D_d$ , however, accumulation of  $D_a$  is stopped when a vehicle passes the stop bar of the intersection even though it may still be in the process of regaining its full operating speed. This of course under-estimates the delay incurred during the acceleration stage. In addition, the portion of  $D_a$  that is ignored may represent a significant part of  $D_a$  if the vehicle is among those first vehicles behind the stop bar. Obviously control delay is a more accurate measurement of vehicular delay caused by intersection control.

Average ICD (AICD) can be calculated analytically by applying formula (9-22)-(9-27) in the new Highway Capacity manual. There are several approaches to measure intersection control delay at the existing intersections:

- Test-car observing
- Path tracking
- Arrival and departure queue observing

HCM expounds the procedures to measure intersection control delay using the arrival departure queue observation in Appendix III. Since CORSIM is a microscopic simulation, it is possible to track individual vehicle profile and make accurate counts of ICD. In addition to its ability to calculate control delay for fixed time intersection, CORSIM can also calculate and accumulate control delay for intersections under sign control (stop or yield sign), or under actuated signal control.

### 2.4.1.3 Person MOEs

The following are the Person MOEs :

- Person Miles
- Person Trips
- Delay Person-Min
- Travel Time Person-Min

## 2.4.2 FRESIM MOEs

### 2.4.2.1 Fresim Link MOEs

The following are the Link MOEs:

- Vehicles In – Number of vehicles that have entered the link since the beginning of the simulation.
- Vehicles Out – Number of vehicles that have been discharged from the link since the beginning of the simulation.
- Lane Changes – Number of lane changes that have occurred on the link since the beginning of the simulation.
- Current Content – Number of vehicles currently on the link.
- Average Content – Total number of vehicle seconds accumulated on the link since the beginning of the simulation divided by the number of seconds since the beginning of the simulation.
- Vehicle Miles – Total distance traveled on the link by all vehicles on the link since the beginning of the simulation.
- Vehicle Minutes – Total time on the link for all vehicles on the link since the beginning of the simulation.
- Total Time (seconds per vehicle) – Link length divide by the average speed (in feet/second) of all vehicles on the link since the beginning of the simulation.
- Move Time (seconds per vehicle) – Total Time per vehicle multiplied by the Ratio of Move Time to Total Time.
- Delay Time (seconds per vehicle) – Total Time per vehicle minus Move Time per vehicle.
- Ratio of Move Time to Total Time – Total Vehicle Minutes minus the total accumulated number of vehicle delay (in seconds), divided by Total Vehicle Minutes. Delay is the difference between the time it would take a vehicle to travel the length of the link if it traveled at the link freeflow speed and the actual time that it takes the vehicle to travel that distance.
- Total Vehicle Minutes per Vehicle Mile – Vehicle Minutes divided by Vehicle Miles.
- Delay Vehicle Minutes per Vehicle Mile – Vehicle Minutes divided by Vehicle Miles multiplied by (1 minus Ratio of Move Time to Total Time).
- Volume – Density multiplied by Speed.
- Density – Average Content divided by the link length divided by the average number of lanes on the link.
- Speed – Vehicle Miles divided by (Vehicle Minutes divided by 60).
- Link Type – Ramp or Mainline

### 2.4.2.2 HOV Link Statistics

Most of these statistics are the same as the link statistics, except broken down by lane, and some MOEs are converted to units per person. That conversion is accomplished by dividing the MOE by the total number of occupants transported by all of the vehicles on the link since the beginning of the simulation. This table also indicates that a lane is an HOV lane or an SOV lane and reports the volume of violators that used the HOV lanes. A violator is a vehicle that does not qualify to use the HOV lane but uses it anyway



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