Calibrating Traffic Simulation Models with Limited Field Data: A Case Study on New Jersey Turnpike

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Motivation

- Microscopic traffic simulation tools have become essential in the field of transportation, serving a wide range of applications.
- Their efficiency heavily relies on the extent of calibration and validation (C&V) performance based on ground-truth data.
- The process becomes even more complex in the presence of limited field data and non-recurrent events.
- Practitioners typically aim for optimal simulation performance within a reasonable timeframe, leading them to opt for a minimal number of calibration parameters.

Objectives

- The objective of this study is to investigate the feasibility of a calibrated model under various simulation scenarios with hypothetical assumptions, particularly under limited sensor coverage and nonrecurrent events.
- The performances of four different scenarios were analyzed to provide insights into the models' ability to handle disruptions and unexpected events in a traffic network with complete and partial data availability.

Methodology

- The methodology used to fulfil the objective of this study is twofold:
  1. Estimating OD demand volume between each OD pair based on complete and limited field data.
  2. Evaluating the calibration of a simulation model under various scenarios, such as incomplete data availability and accident events.

Simulation Model Development

- SUMO microscopic traffic simulation software was used to model the simulation scenarios.
- The study network is part of the larger New Jersey Turnpike (NJTPK), a six-mile section from Interchange 12 to 13A.
- Only the northbound direction was considered for the analysis.
- There are two possible route choices, namely cars-only lane, and cars-and-trucks lane.
- Induction loop detectors, placed on the main road before and after each interchange, were used to record the hourly demand volume.

Dataset

- The Electronic Toll Collection database of the NJTPK was utilized to extract valuable traffic-related information.
- In addition, this study used the NJTPK TMC's incident logs and the state police's accident database to identify an accident scenario.

Analysis Scenarios

Four scenarios were selected with an eye toward practical implications.

Scenario I, a base case scenario was calibrated and validated based on the vehicle-by-vehicle information from the ETC system.

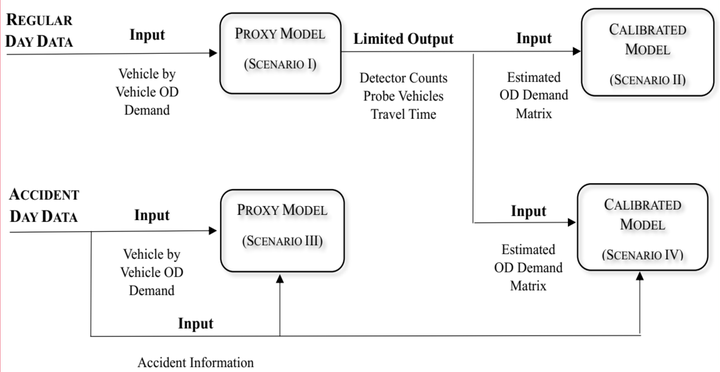
Scenario II, the OD demand values, estimated from the counting sensors in Scenario I, were used as the demand inputs.

Scenario III, a crash was simulated using the proxy model, but with the vehicle-by-vehicle OD information of the crash day.

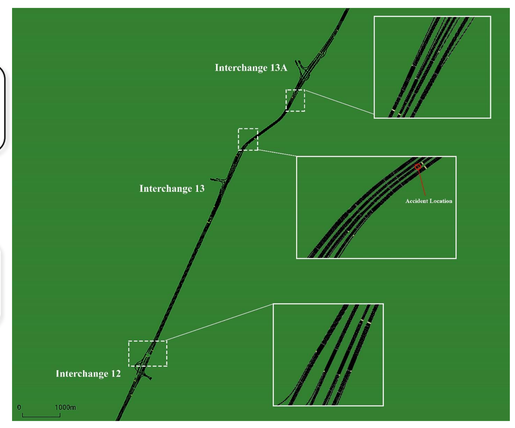
Scenario IV, was developed using the calibrated network of Scenario II and the crash information of Scenario III.

OD Estimation

- The generalized least square formulation was used to minimize differences between estimated and observed traffic counts.
- Various constraints were introduced to the problem, which were based on the physical properties of roadways and the educated guesses recommended by traffic analysts familiar with the studied network.



Simulation Analyses Scenarios



The Simulation Network of Study Area.

Findings

- Results demonstrate the feasibility of a calibrated simulation model, under various hypothetical scenarios, in terms of average travel time and throughput volume between each OD pair.
- Scenario I revealed that the observed and simulated values exhibit almost similar performance. However, there is a slight difference between their hourly volume.
- The hourly volume in Scenario II is remarkably different from that of Scenario I and observed values, however loop detector counts on the mainline exhibit a close match between the observed and simulated values.
- Scenario III and Scenario IV could poorly reproduce the observed values in terms of travel time and demand volume.

The Actual and Estimated Loop Detector Counts (7 – 9 AM)

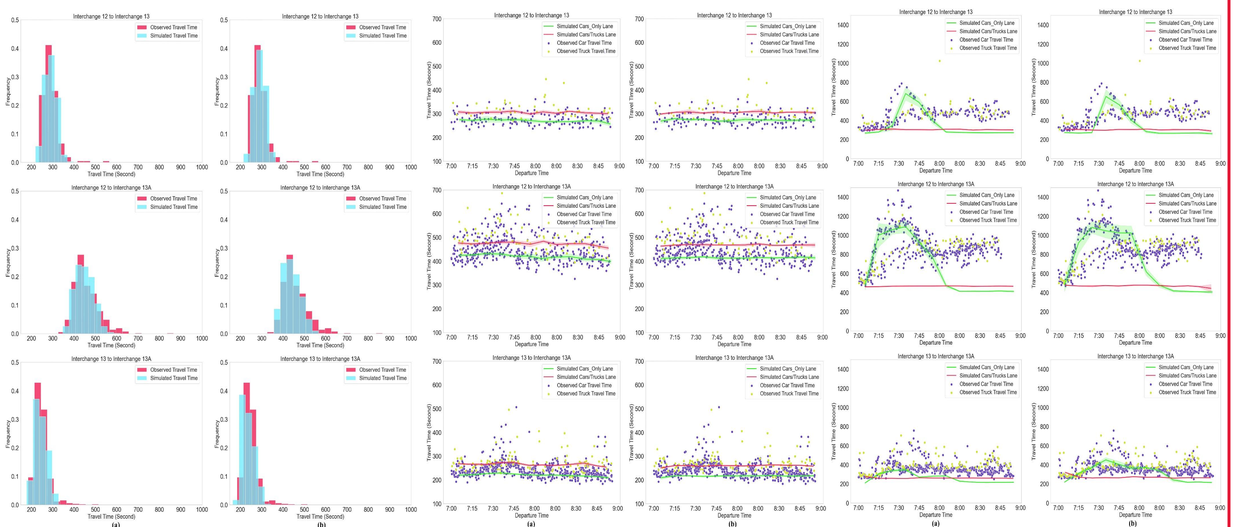
		Detector 1	Detector 2	Detector 3	Detector 4
Detector Count	Observed	18,374	19,517	22,146	18,075
	Estimated	18,409	19,648	22,337	18,311

The Actual and Estimated OD Demand Matrices (7 – 9 AM)

		Interchange 12	Interchange 13	Interchange 13A	North
South	Observed	645	1,532	3,567	12,630
	Estimated	1,478	1,397	2,641	12,893
Interchange 12	Observed	-	220	536	1,032
	Estimated	-	192	815	1,710
Interchange 13	Observed	-	-	761	3,620
	Estimated	-	-	1,619	2,659
Interchange 13A	Observed	-	-	-	793
	Estimated	-	-	-	1,049

Observed and Simulation Output at Morning Period (7 – 9 AM)

		Travel Time (Second)	Volume (Veh/Hour)
Observed Value (Regular Day)	12 to 13	287	211
	12 to 13A	456.3	504
	13 to 13A	247	722
Observed Value (Accident Day)	12 to 13	462	256
	12 to 13A	861	495
	13 to 13A	366	742
Scenario I	12 to 13	[288 - 291]	[212 - 213]
	12 to 13A	[447 - 449]	[510 - 512]
	13 to 13A	[243 - 245]	[739 - 741]
Scenario II	12 to 13	[289 - 292]	[190 - 191]
	12 to 13A	[439 - 440]	[787 - 789]
	13 to 13A	[236 - 237]	[1,610 – 1,612]
Scenario III	12 to 13	[320 - 328]	[262 - 263]
	12 to 13A	[608 - 630]	[519 - 521]
	13 to 13A	[293 - 303]	[773 - 775]
Scenario IV	12 to 13	[321 - 332]	[190 - 191]
	12 to 13A	[567 - 588]	[788 - 790]
	13 to 13A	[261 - 263]	[1,612 – 1,614]



The Observed and Simulated Travel Time Histogram for each OD pairs: (a) Scenario I. (b) Scenario II.

The Observed and Simulated Travel Time versus Departure Time: (a) Scenario I. (b) Scenario II.

The Observed and Simulated Travel Time: (a) Scenario III. (b) Scenario IV

Conclusions

- The results demonstrated that:
  - The calibrated simulation model performed reasonably well when fed with complete input data (Scenario I).
  - Despite the matching travel times in Scenario II, the OD demand volume varies significantly.
  - In the presence of a non-recurrent event, the simulation model could not precisely reproduce the observed values (Scenario III).
  - Scenario IV revealed a considerable difference between observed and simulated values.
  - This result was anticipated since the accident occurred on the mainline, and the estimated OD demand matrix matches the mainline detector counts, assuring accurate traffic flow at and upstream of the accident location.
  - In the case of an accident occurring at on-ramps or off-ramps, similar satisfactory results would not be achieved, as the estimated demand between OD pairs was substantially different from the observed ones.

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