Traffic Prediction on the Road Network of Isfahan Province Using Graph-Based Spatiotemporal Models (T-GCN and GTN-GCN)

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1. Problem Statement

Most graph-based traffic prediction methods—particularly those that leverage Graph Neural Networks (GNNs)—are developed and evaluated on high-frequency datasets. For example, in the recent paper *GTN-GCN: Real-Time Traffic Forecasting Using Graph Neural Networks* (Applied Computational Intelligence and Soft Computing, 2025), the T-GCN model is reported to achieve MAE = 2.68 and RMSE = 5.33 on the benchmark METR-LA dataset (a collection of 5-minute interval traffic measurements from 207 sensors in Los Angeles).

However, publicly available Iranian traffic datasets such as those published by the national data portal data.gov.ir are recorded at daily resolution. This coarse temporal format presents a unique challenge for spatiotemporal models. While the spatial connections between road segments can be naturally represented as a graph, the lack of fine-grained temporal dynamics raises questions about the applicability and performance of established models like T-GCN.

This research project seeks to answer the following:

> **Can graph-based spatiotemporal models such as T-GCN and the more recent GTN-GCN be effectively applied to low-resolution daily traffic data from Isfahan Province, and how do their performances compare with established results on high-frequency benchmarks like METR-LA?**

Addressing this will not only deepen understanding of model transferability across resolutions and regions, but also provide practical insights into modeling Iranian road traffic.

2. Proposed Methodology

Base Models:

T-GCN

T-GCN integrates Graph Convolutional Networks (GCN) to capture spatial dependencies in road networks and GRU units to model temporal dynamics.
 Code repositories:

- https://github.com/zouchangjie/T-GCN
- https://github.com/lehaifeng/T-GCN

GTN-GCN (Graph Temporal Network + Graph Convolutional Network)

 designed to address several limitations of earlier graph-based traffic forecasting models. Unlike T-GCN, which relies on fixed temporal gating through GRUs, GTN-GCN introduces learnable temporal kernels that adaptively capture time-dependent patterns while simultaneously modeling spatial dependencies through GCN layers.

This hybrid design enables the model to better represent long-range temporal correlations and dynamic spatial interactions, leading to significant performance improvements on standard benchmarks. For example, on the METR-LA dataset, GTN-GCN reports lower error metrics than T-GCN, with T-GCN achieving MAE = 2.68 and RMSE = 5.33, as documented in the study.

The full article is available at:
 https://onlinelibrary.wiley.com/doi/full/10.1155/acis/5572638

In this project, T-GCN serves as the classical baseline model, while GTN-GCN is used as a more recent comparator that reflects the current state of the art in graph-based traffic forecasting.

Dataset: Isfahan Traffic Counters (2018)

We use daily-count traffic data from the Isfahan Province traffic control stations, available from the national open data portal:

- https://data.gov.ir/dataset/?tags=%D8%A7%D8%B5%D9%81%D9%87%D8%A7%D9%86

Nodes: Road segments such as code 214953 (Kashan–Ardestan)
Temporal resolution: Daily (00:00–00:00), 1440-minute window
Features:

- Total traffic volume
- Average speed
- Five vehicle-class counts
- Speeding / distance / overtaking violations
  Period: Early August 2018 (Mordad 1397; expandable using monthly datasets)

Extended Feature Description

The dataset provides a rich set of daily aggregated traffic attributes for each monitored road segment. Each record contains the following columns:

- **Segment Code:** Unique numeric identifier for each road station.
- **Segment Name :** Descriptive name of the road or highway.
- **Start / End Time:** Start and end timestamps of the 24-hour measurement window.
- **Duration:** Always 1440 minutes, indicating a full-day recording.
- **Total Vehicle Count:** Total number of vehicles passing during the day.
- **Vehicle Class Counts (Class 1–5):** Number of vehicles in five distinct categories (motorcycles, light vehicles, heavy trucks, buses, etc.).
- **Average Speed:** Mean measured vehicle speed over the 24-hour period.
- **Speed Violations:** Count of vehicles exceeding the speed limit.
- **Unsafe Distance Violations:** Number of detected cases of insufficient following distance.
- **Illegal Overtaking:** Count of overtaking violations.
- **Estimated Count:** Adjusted traffic volume after station calibration.

This multi-feature structure enables modeling of not only overall traffic volume but also composition, behavior, and violation patterns, offering significantly richer information than standard datasets such as METR-LA.

Graph construction:
- Spatial k-nearest neighbors
- OpenStreetMap topology (OSM Isfahan network)

This dataset forms the basis of the graph, where stations are nodes and edges are determined by geographical adjacency or road network topology.

Sample (Dates recorded in the Persian calendar):

```
| code    | date       | volume | speed
|-----------|---------------|------------|--------|
| 214953 | 1397/05/01 | 4090    | 569  |
| 214953 | 1397/05/02 | 3914    | 580  |
```

Processing Pipeline

1. **Preprocessing:**

   Construct feature tensor

   $$X \in \Re^{N \times T}$$

   where N is the number of road segments and T the number of days.
   Each $X{n,t}$ contains the volume or multi-feature vector of segment *n* on day *t*.

2. **Graph Construction:**

   $A \in \Re^{N \times N}$ from spatial coordinates

3. **Training:**

   Optimize T-GCN using loss:

   $$L = \frac{1}{T} \sum_{t=1}^{T} ||\widehat{X}^t - X^t||_2^2$$

4. **Evaluation (vs. METR-LA) :**
   - MAE (Mean Absolute Error)
   - RMSE (Root Mean Squared Error)
   - MAPE (Mean Absolute Percentage Error)

3. Expected Contributions

Comparative Analysis

Metric	METR-LA	Esfahan Roads (Predicted)
Nodes	207 sensors kaggle	10-50 segments data

Time	5-min arxiv	Daily data
MAE	**2.68 mph** wiley	To be evaluated
RMSE	**5.33 mph** wiley	To be evaluated

Due to the coarse temporal resolution of Iranian traffic datasets (daily aggregates), the performance on the Esfahan network is expected to be lower than on METR-LA. However, the exact margin of degradation will be quantified experimentally.

Novelty

- First systematic application of T-GCN to Iranian provincial road data
- Identifies performance gap caused by coarse temporal sampling
- Investigates local traffic behavior (e.g., Thursday/Friday peaks)
- Opens the door for GNN-based transport forecasting in Iran

Risks / Challenges

- Graph sparsification due to limited sensors
- Risk of overfitting → addressed using cross-validation across multiple months
- Variability in station reliability
- Temporal smoothness reducing GRU efficiency

4. References

Foundational Papers & Code

- Zhao et al., *T-GCN: A Temporal Graph Convolutional Network*
  https://arxiv.org/abs/1811.05320
- https://onlinelibrary.wiley.com/doi/full/10.1155/acis/5572638

- GitHub Implementations

  - https://github.com/zouchangjie/T-GCN
  - https://github.com/lehaifeng/T-GCN

- Scribd summary

  https://www.scribd.com/document/790604638/T-GCN-A-Temporal-Graph-Convolutional-Network-for-Traffic-Prediction

Traffic Prediction & GNN Research

- 2024 GNN advances in traffic prediction
  https://www.scitepress.org/Papers/2024/129022/129022.pdf

- Alternative spatiotemporal models
  https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5220881

- IET ITS article
  https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/itr2.12224

- ScienceDirect traffic studies
  https://www.sciencedirect.com/science/article/abs/pii/S2352485525000970

- IEEE ITS applications
  https://ieeexplore.ieee.org/iel8/6287639/6514899/11097318.pdf

- ACM ST-GNN survey
  https://dl.acm.org/doi/10.1145/3716554.3716619

Datasets

- METR-LA
  https://www.kaggle.com/datasets/annnnguyen/metr-la-dataset

- Isfahan datasets

  https://data.gov.ir/dataset/?tags=%D8%A7%D8%B5%D9%81%D9%87%D8%A7%D9%86

  https://data.gov.ir/dataset/?q=&_groups_limit=0&tags=%D9%81%D8%B1%D9%88%D8%B1%D8%AF%DB%8C%D9%86+97&tags=%D8%A7%D8%B3%D8%AA%D8%A7%D9%86+%D8%A7%D8%B5%D9%81%D9%87%D8%A7%D9%86&organization=11c99d566b1018225779a80acdcceac67a1881d1&groups=transportation

Regional Traffic Studies

- Journal of Road Systems (Iran)
  https://jrsgr.sru.ac.ir/article_2122.html