Yusong ZHOU, Xiaoyu JIANG, Shu SUN, Xinmin ZHANG, Yuanqiu MO, Zhihuan SONG, 2025. MltAuxTSPP: a unified benchmark for deep learning-based traffic state prediction with multi-source auxiliary data. *Frontiers of Information Technology & Electronic Engineering*, 26(10):1984-1999. https://doi.org/10.1631/FITEE.2500169

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MltAuxTSPP: a unified benchmark for deep learning-based traffic state prediction with multi-source auxiliary data

Key words: Traffic prediction; Benchmark platform; Deep learning; Multi-source auxiliary data

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Motivation

- Existing traffic prediction models rely solely on traffic-related data, limiting performance.
- Multi-source auxiliary data (weather, temporal features) are underutilized due to poor generality and scalability of integration methods.
- Lack of a unified benchmark hinders fair model comparison and quantification of auxiliary data benefits.

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Main idea

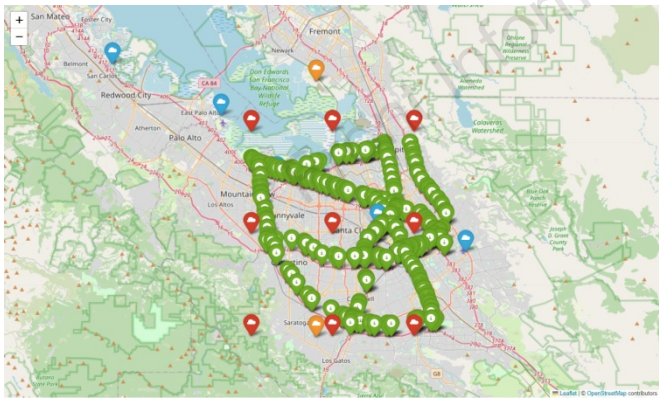
- Propose MltAuxTSPP, a **general and scalable** framework integrating **multi-source auxiliary data**.
- Design a **unified data container (UDC)** to standardize heterogeneous data storage and management.
- Develop **fusion embedding modules** to convert multi-source data into unified hidden representations for downstream models.
- Augment classic datasets (METR-LA, PEMS-BAY) with weather and temporal features for standardized evaluation.

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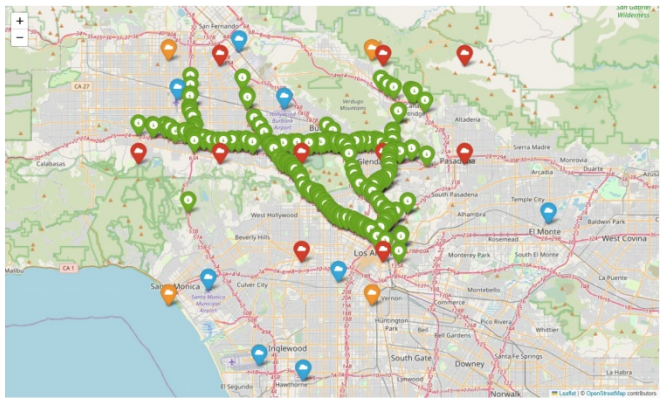
Method

1. Data processing

- Augment METR-LA and PEMS-BAY with three weather datasets (ERA5-Land, ERA5-HEAT, GH-ISD) and three temporal features (minute of the hour, MoH; hour of the day, HoD; day of the week, DoW).
- Preprocessing: temporal interpolation (5-min frequency), spatial alignment, and Z-score normalization.



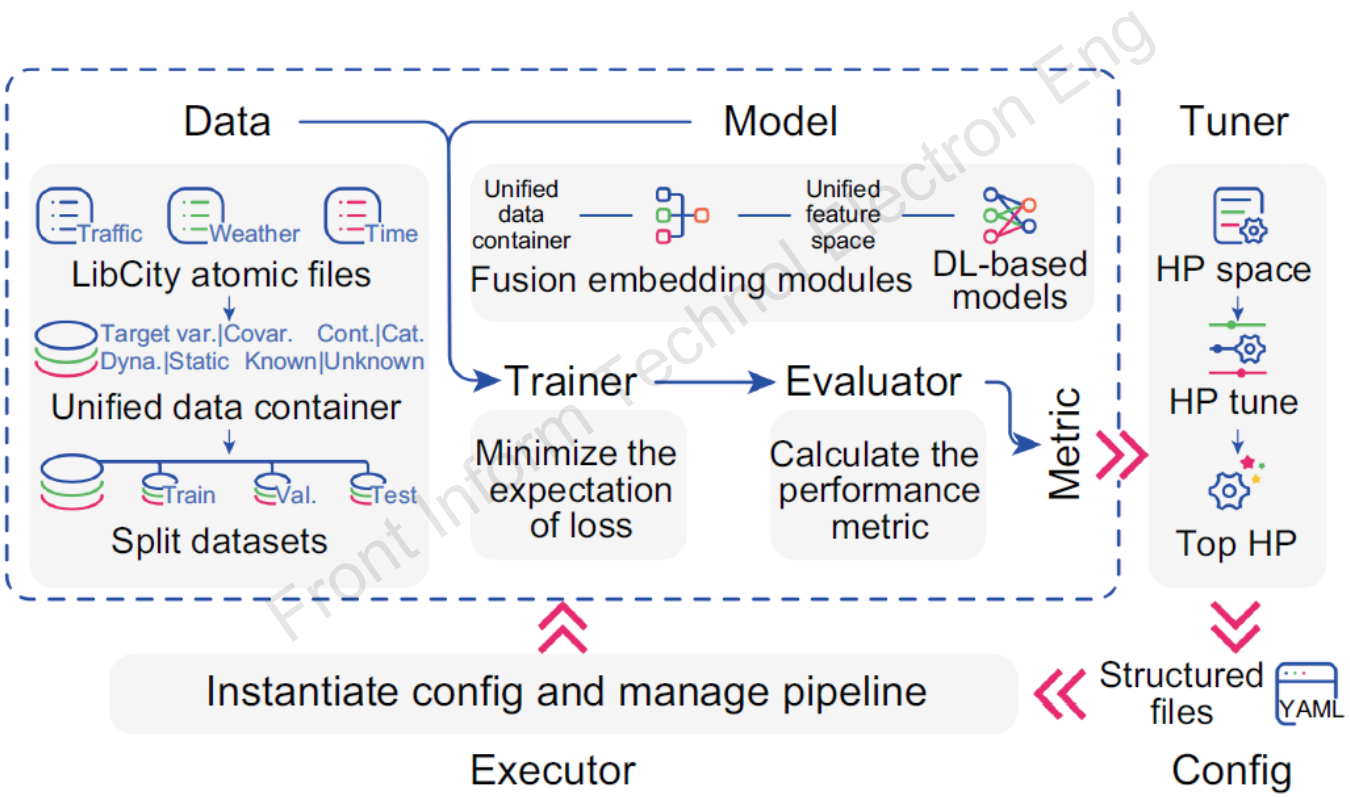
(a) PEMS-BAY



(b) METR-LA

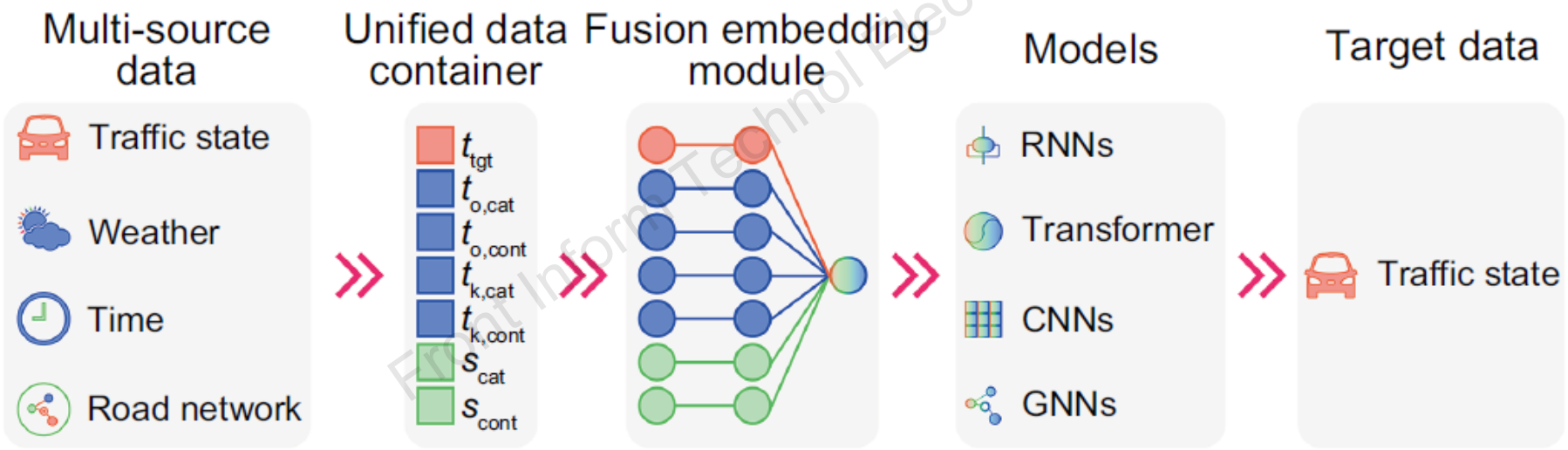
Method

2. Benchmarking system



Method

3. Multi-source auxiliary data fusion framework for traffic state prediction



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Method

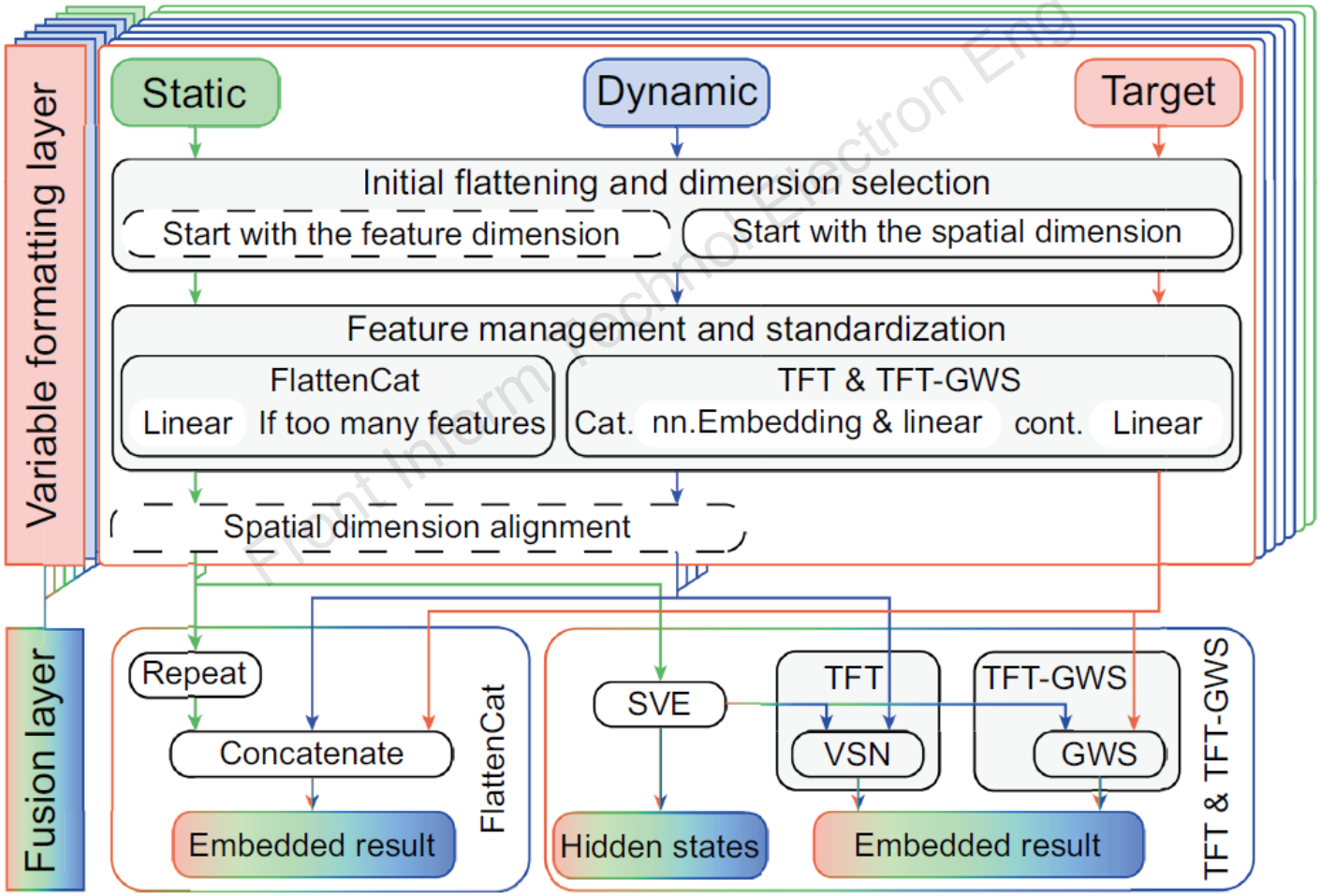
4. UDC

Component	Source	Temporal	Observation	Data type
t_{tgt}	Target	Dynamic	Unknown	Continuous, categorical
s_{cont}	Covariates	Static	Known	Continuous
s_{cat}			Known	Categorical
$t_{\mathrm{k,cont}}$		Dynamic	Known	Continuous
$t_{\mathrm{k,cat}}$			Known	Categorical
$t_{\mathrm{o,cont}}$			Unknown	Continuous
$t_{\mathrm{o,cat}}$			Unknown	Categorical

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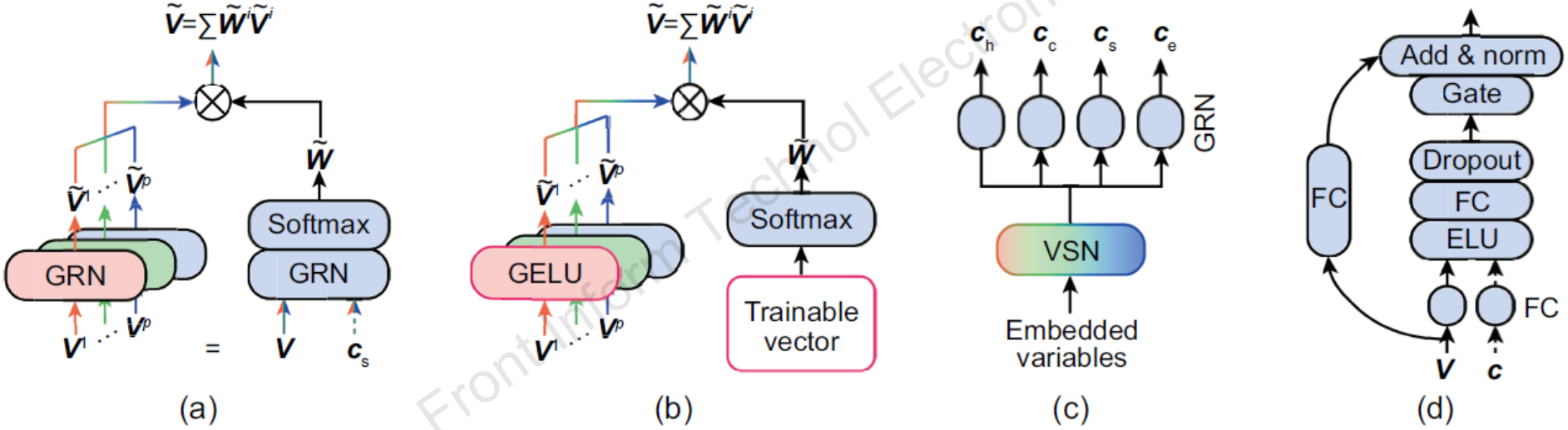
Method

5. Fusion embedding modules



Method

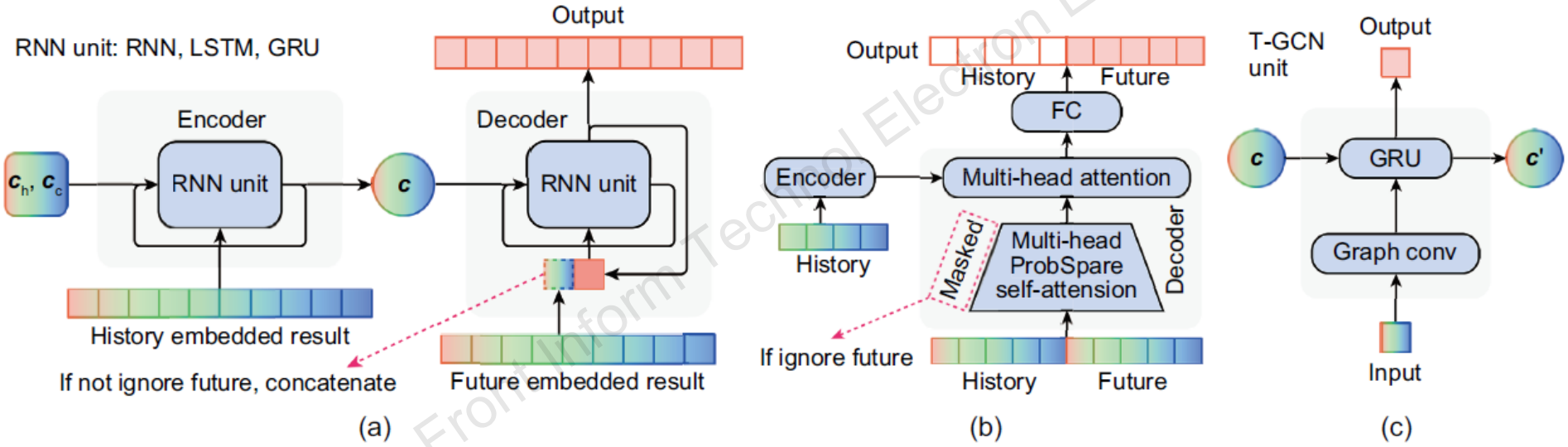
5. Fusion embedding modules



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Method

5. Fusion embedding modules



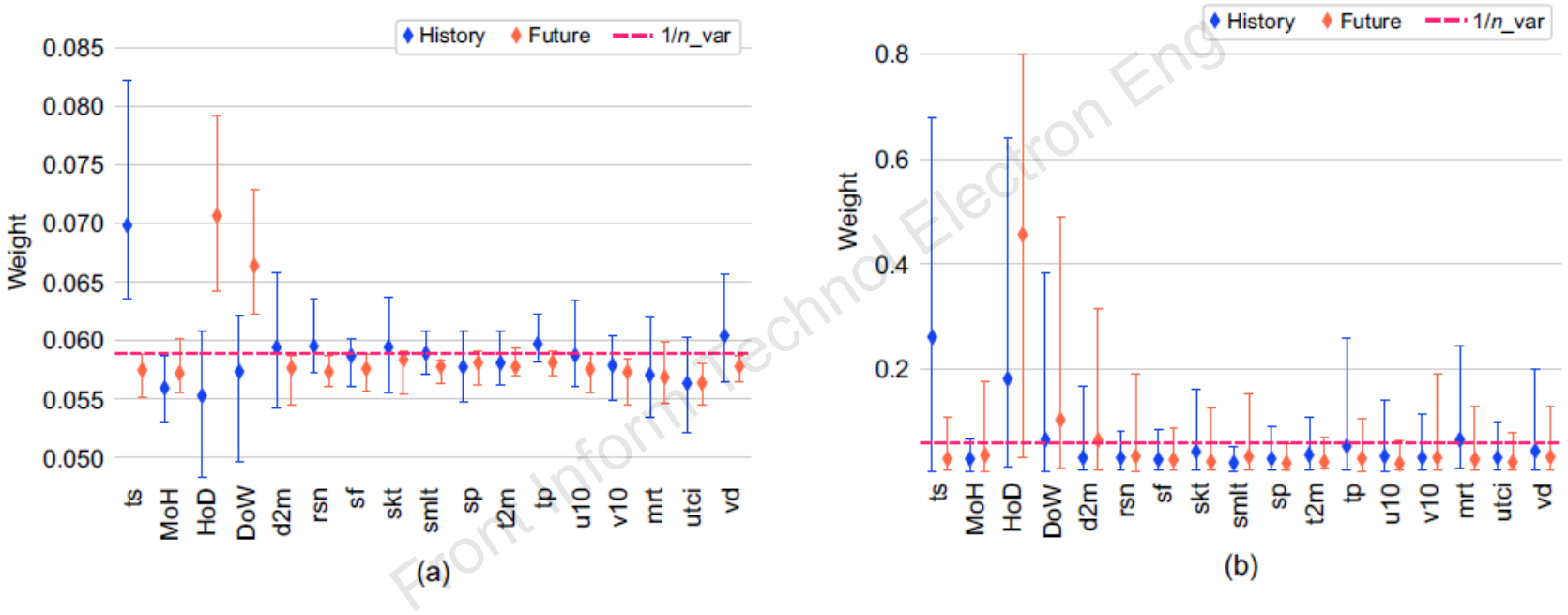
Fusion embedding modules and models: (a) Seq2Seq; (b) Informer; (c) T-GCN unit

Major results

- Bandwidth improvement: Auxiliary data enhance long-term (48/96 steps) prediction accuracy (TFT/TFT-GWS).
- Efficiency: TFT-GWS reduces parameters vs. TFT with comparable performance.
- Future information gain: Known future covariates (e.g., HoD/DoW) further boost accuracy.
- Nonlinear fusion modules (TFT/TFT-GWS) outperform linear FlattenCat, especially in long-term forecasting.
- Single-node tasks benefit more from auxiliary data; multi-node models capture spatial interactions effectively.
- Historical traffic speed, future HoD/DoW, and precipitation are top predictive features.

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Major results



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Variable selection weights in Informer: (a) with TFT-GWS; (b) with TFT

Conclusions

- MltAuxTSPP provides a unified, scalable platform for multi-source traffic prediction, solving data integration and fair comparison challenges.
- Fusion embedding modules effectively leverage weather and temporal features to improve long-term forecasting robustness.
- The framework serves as a foundation for advancing intelligent transportation system (ITS) research and applications.

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