Data Driven Methods for Train Delay Prediction

TIONG KAH YONG, LUND UNIVERSITY

Content

Introduction

Research design

Answering research questions

Conclusion and future research

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Introduction

- Train delay is defined as the *deviation of actual train events from scheduled train events.*

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- *High-capacity utilisation* and *heterogeneous traffic* make the railway network susceptible to delays.

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Train delay prediction model

- *Predicting* the expected train traffic conditions at a future time

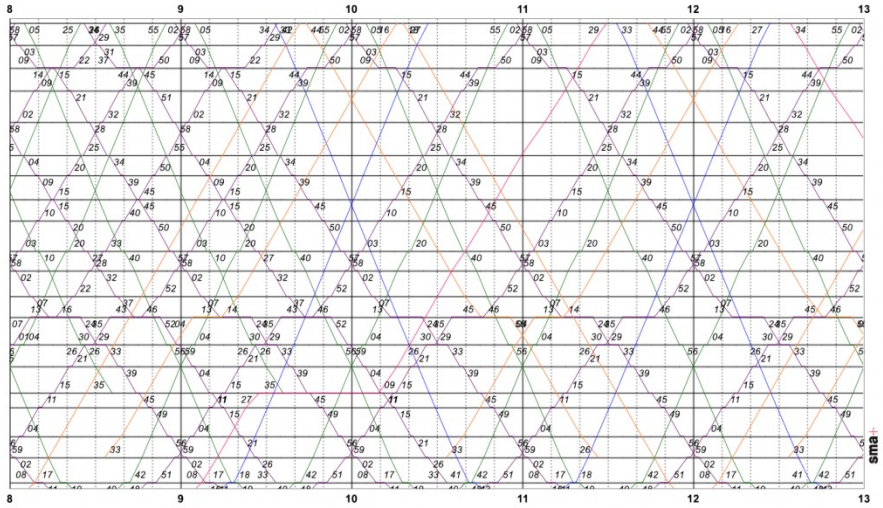
Train delay prediction model

- *Predicting* the expected train traffic conditions at a future time.

- *Input* for solving many problems related to train traffic management.

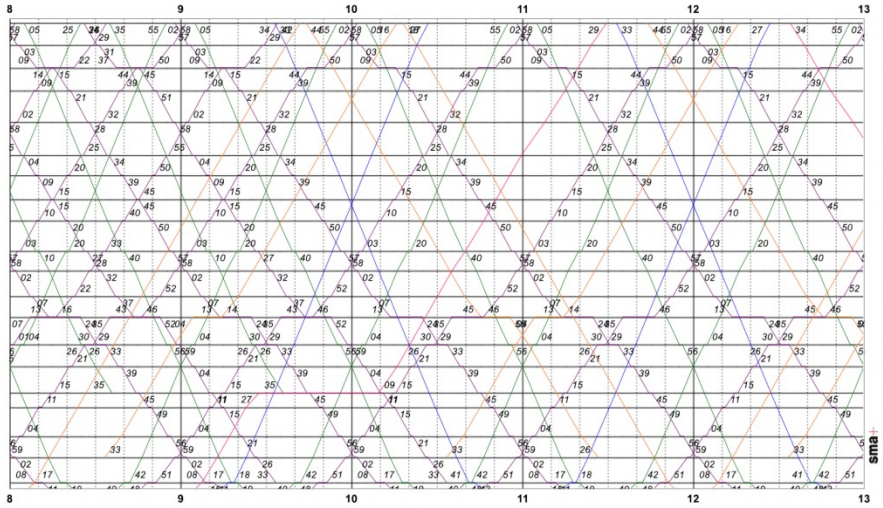
Train delay prediction model

Train delay prediction model



Timetable planning

Train delay prediction model



Timetable planning

Real-time train management

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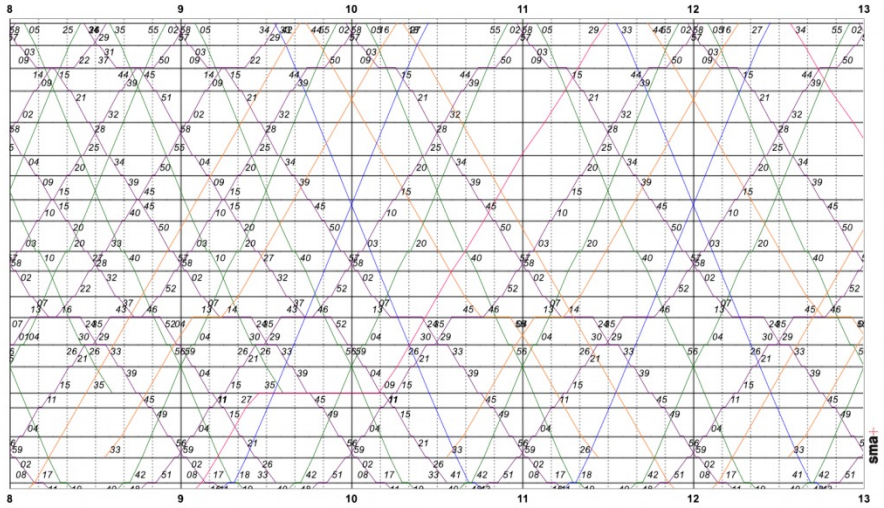
Train delay prediction model



Timetable planning

Real-time train management

Reliable passenger information system

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Research design

Research gap

Research gap

- *Insufficient understanding* of existing train delay prediction models.

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Research gap

- *Insufficient understanding* of existing train delay prediction models.

- There is a lack of innovation in developing train delay prediction models with *practical applications*.

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Research aim

To increase understanding of data-driven train delay prediction models

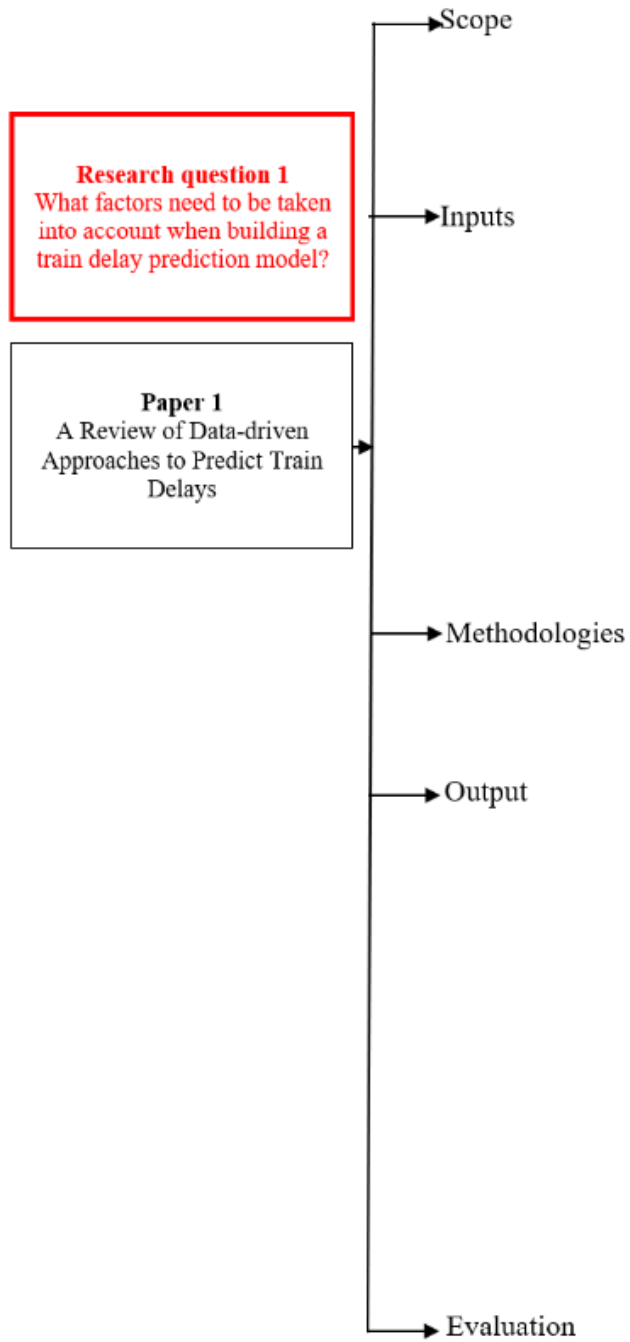
Research questions, papers and their connections

Research question 1
What factors need to be taken into account when building a train delay prediction model?

To increase *our understanding of the various aspects* that must be considered.

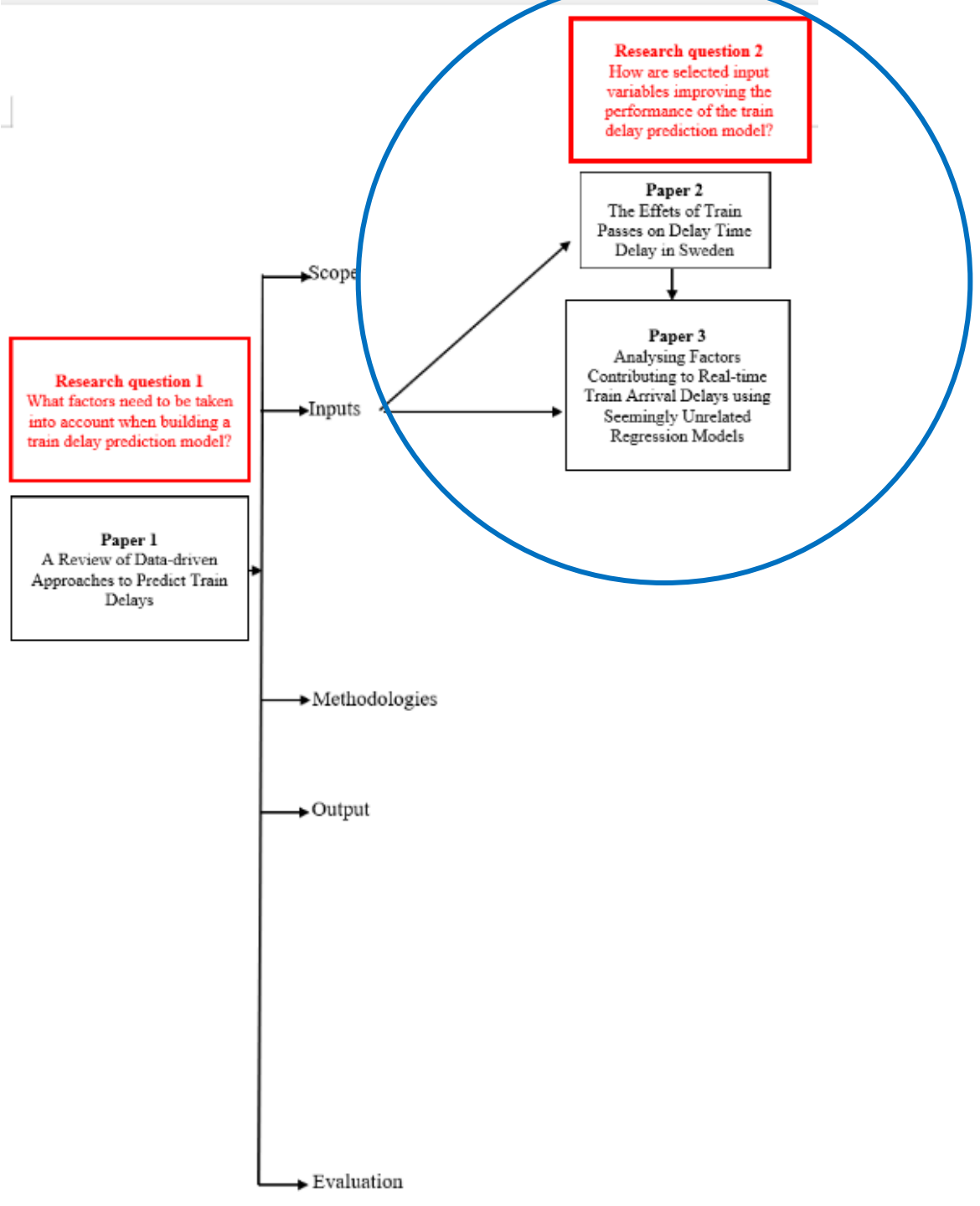
Research question 1
What factors need to be taken into account when building a train delay prediction model?

Paper 1
A Review of Data-driven Approaches to Predict Train Delays


Research question 1
What factors need to be taken into account when building a train delay prediction model?
Paper 1
A Review of Data-driven Approaches to Predict Train Delays
Scope
Inputs
Methodologies
Output
Evaluation

Research question 2
How are selected input variables improving the performance of the train delay prediction model?

To *identify useful input variables* to enhance model performance


Research question 2
How are selected input variables improving the performance of the train delay prediction model?
Paper 2
The Effets of Train Passes on Delay Time Delay in Sweden
Paper 3
Analysing Factors Contributing to Real-time Train Arrival Delays using Seemingly Unrelated Regression Models
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Research question 1
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Inputs
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Methodologies
Output
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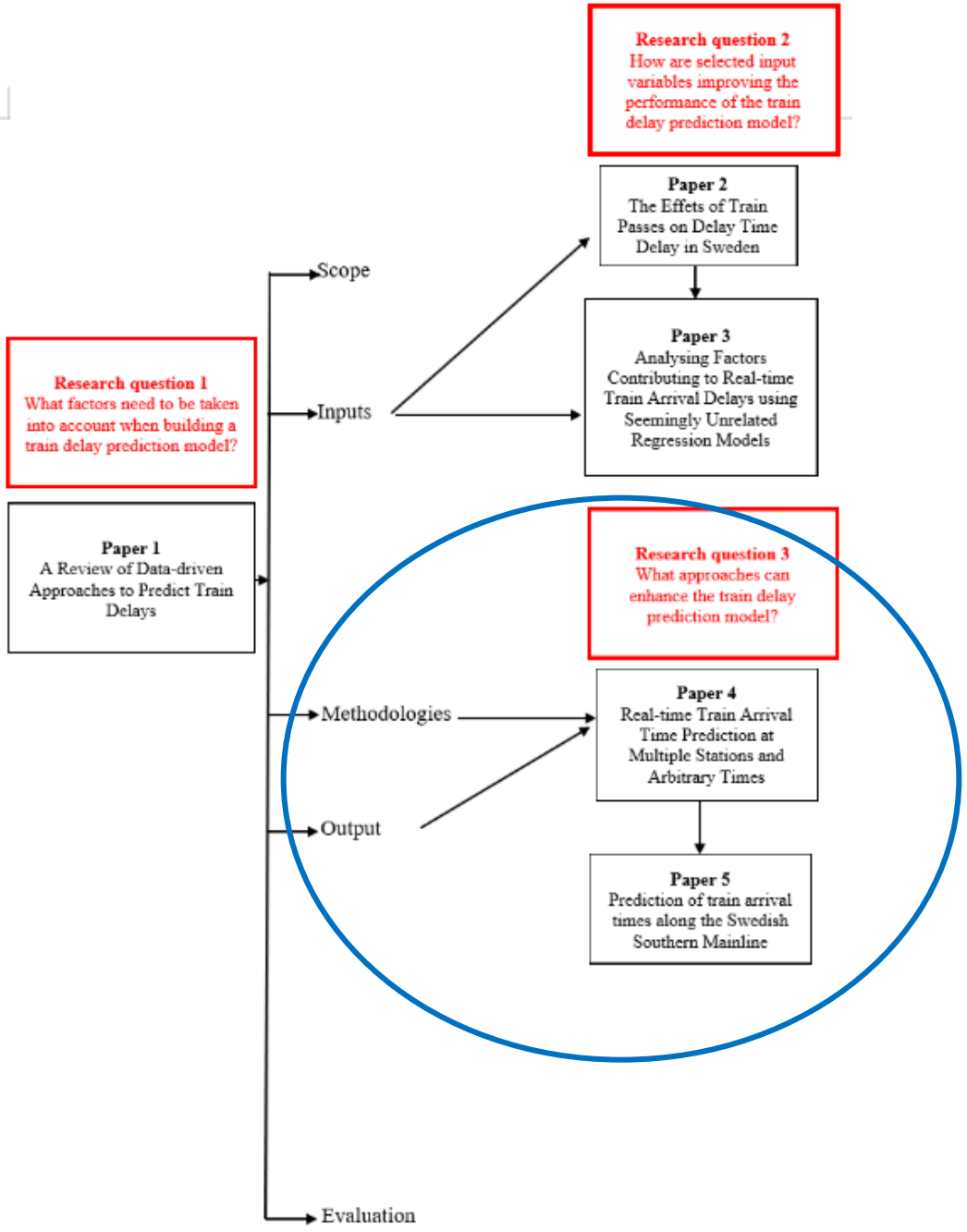
Research question 3
What approaches can enhance the train delay prediction model?

The *formulation of innovative technical solutions* to address the current modelling challenges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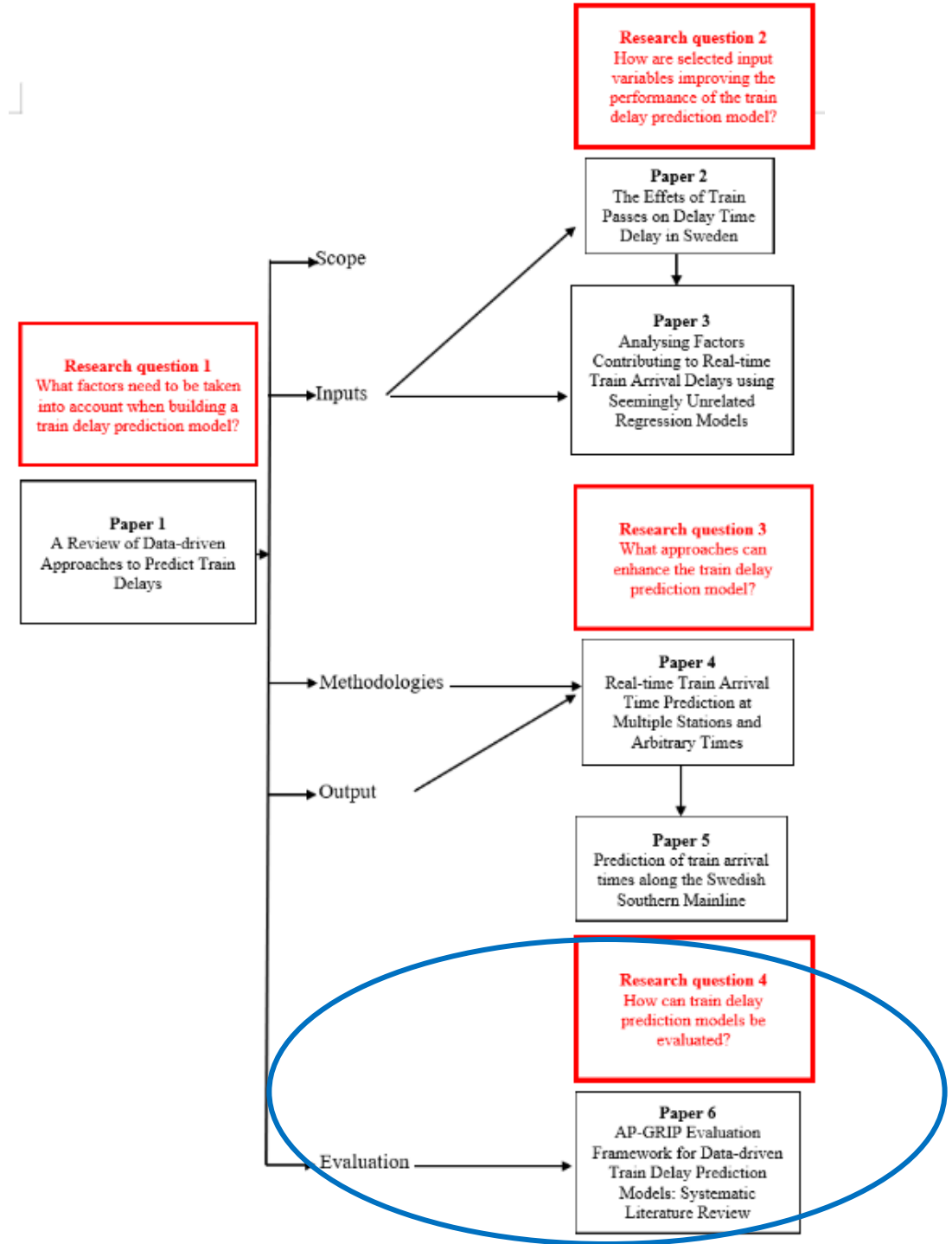
Paper 4
Real-time Train Arrival Time Prediction at Multiple Stations and Arbitrary Times
Output
Paper 5
Prediction of train arrival times along the Swedish Southern Mainline
Evaluation

Research question 4
How can train delay prediction models be evaluated?

To thorough assessment of train delay prediction models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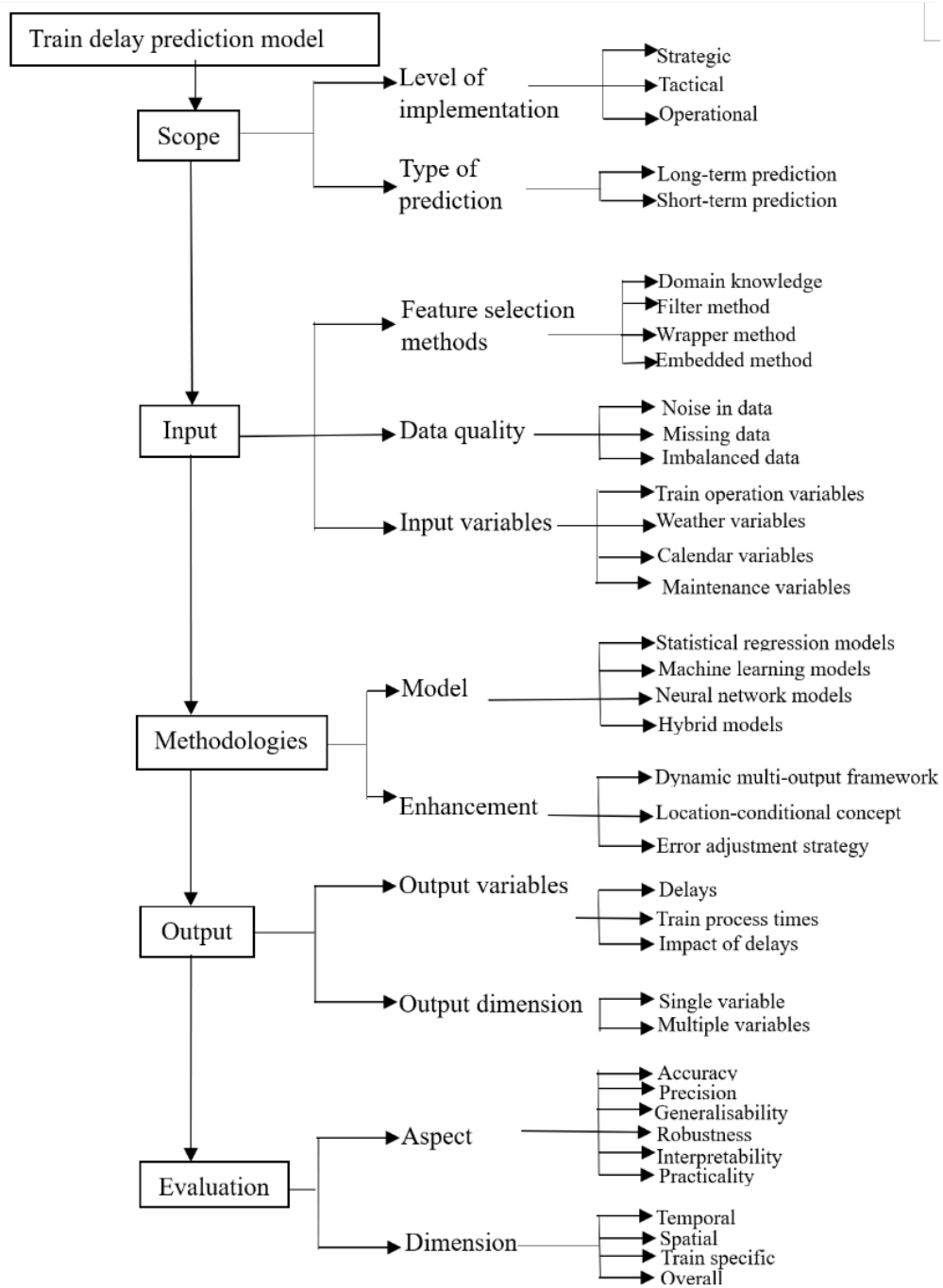
Paper 6
AP-GRIP Evaluation Framework for Data-driven Train Delay Prediction Models: Systematic Literature Review

Answering research questions

Research question 1

What factors need to be taken into account when building a train delay prediction model?


Train delay prediction model
Scope
Level of implementation
Strategic
Tactical
Operational
Type of prediction
Long-term prediction
Short-term prediction
Input
Feature selection methods
Domain knowledge
Filter method
Wrapper method
Embedded method
Data quality
Noise in data
Missing data
Imbalanced data
Input variables
Train operation variables
Weather variables
Calendar variables
Maintenance variables
Methodologies
Model
Statistical regression models
Machine learning models
Neural network models
Hybrid models
Enhancement
Dynamic multi-output framework
Location-conditional concept
Error adjustment strategy
Output
Output variables
Delays
Train process times
Impact of delays
Output dimension
Single variable
Multiple variables
Evaluation
Aspect
Accuracy
Precision
Generalisability
Robustness
Interpretability
Practicality
Dimension
Temporal
Spatial
Train specific
Overall

Scope

Long-term prediction models

Short-term prediction models

Scope

Long-term prediction models

- Study how different factors affect train delays
- Use historical data
- Predict delays several days or months in advance
- For both strategic and tactical train traffic planning

Short-term prediction models

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Scope

Long-term prediction models

- Study how different factors affect train delays
- Use historical data
- Predict delays several days or months in advance
- For both strategic and tactical train traffic planning

Short-term prediction models

- Focus on making accurate predictions
- Use real-time and historical data
- Predict near-future train delays
- For operational level traffic management

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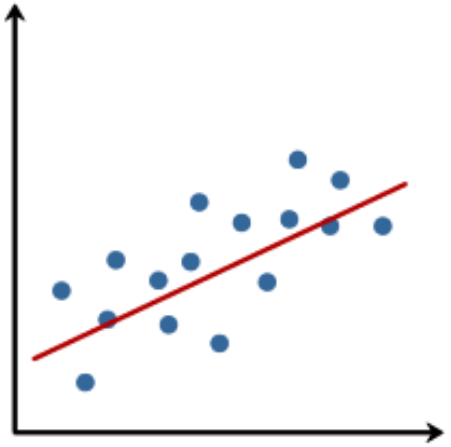
Method

Method



Statistical regression

- It has limitations for modelling complex and non-linear relationships

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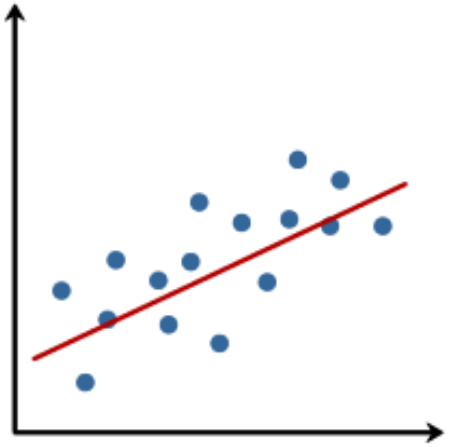
Method



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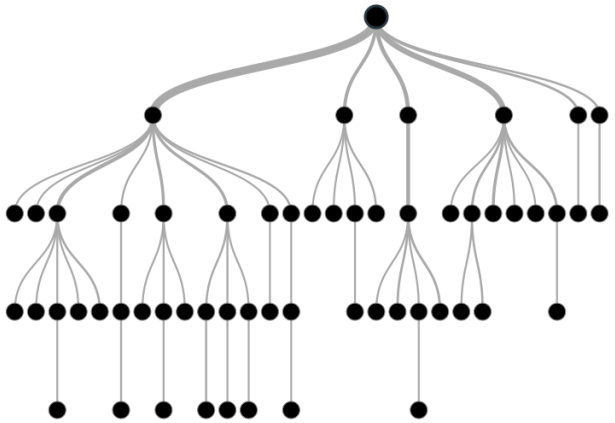

Conventional machine learning

- Less interpretable
- Requires human-engineered spatiotemporal features to capture the spatial and temporal flow patterns of data

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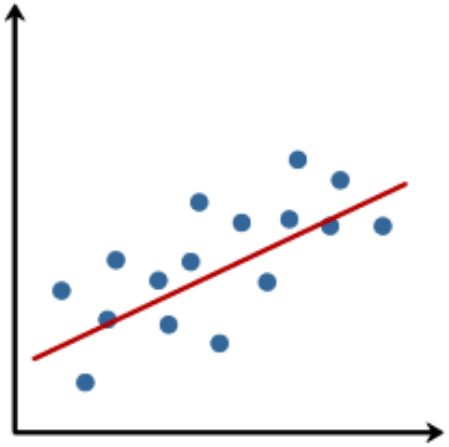
Method



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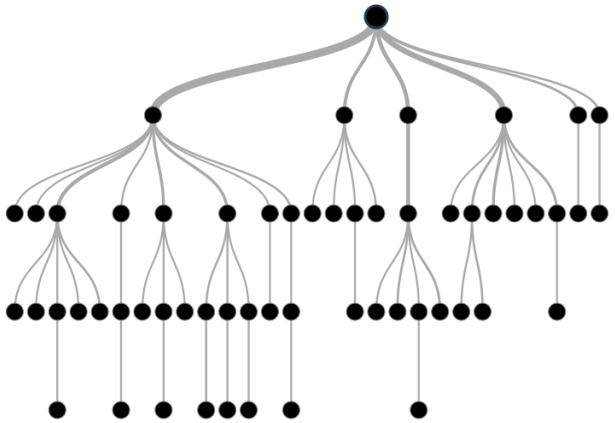

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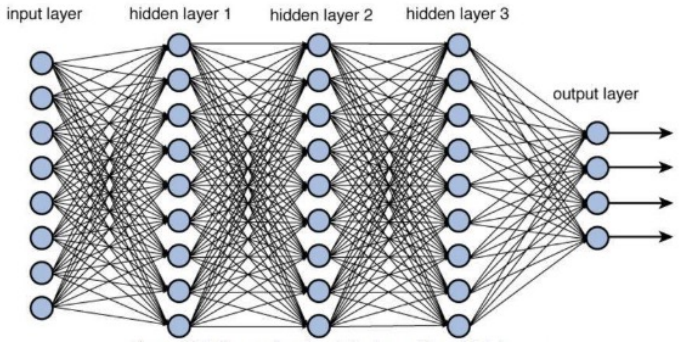

Neural Network

- Automatic learning of spatiotemporal representations from data
- Flexibility to integrate different architectures into hybrid models

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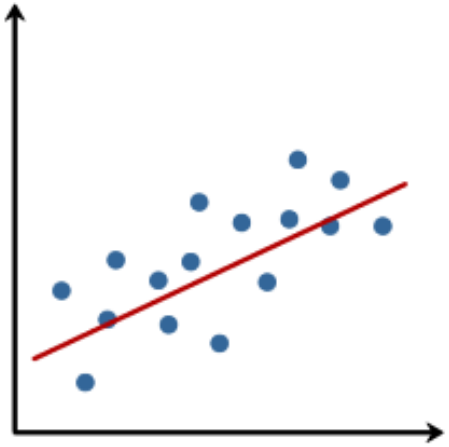
Method



Statistical regression

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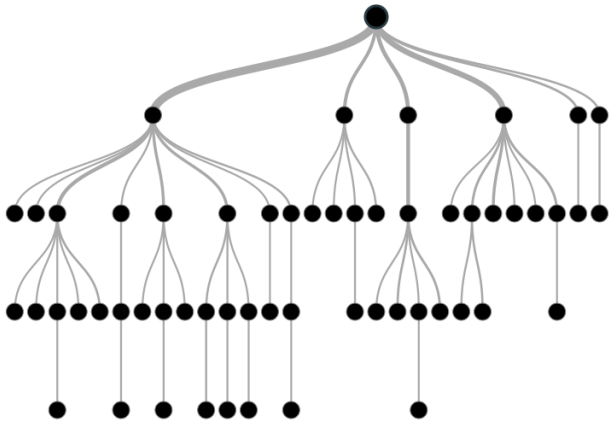

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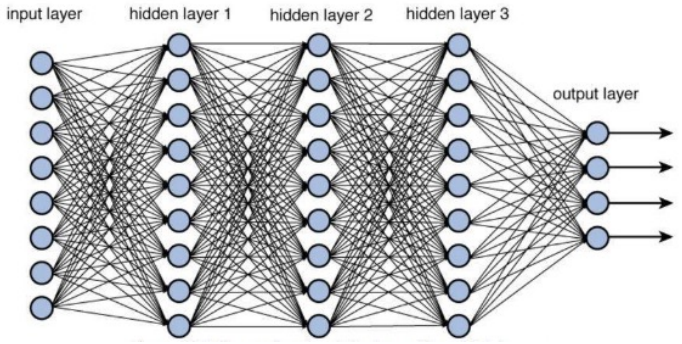

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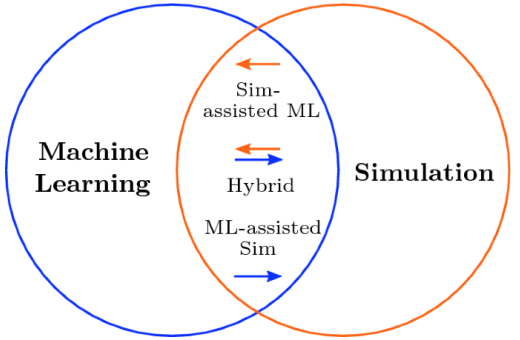

Hybrid model

- Multiple base models with uncorrelated prediction errors

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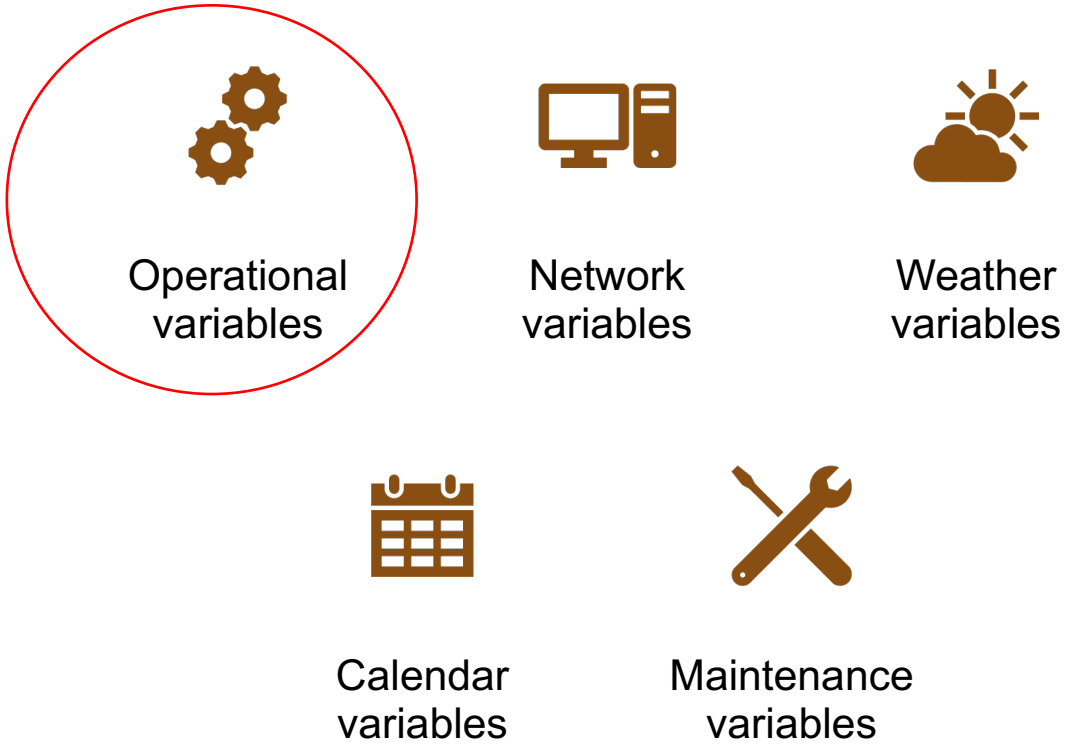
Research question 2

How are selected input variables improving the performance of the train delay prediction model?

Input



Findings

- The train operation data greatly influences delays.

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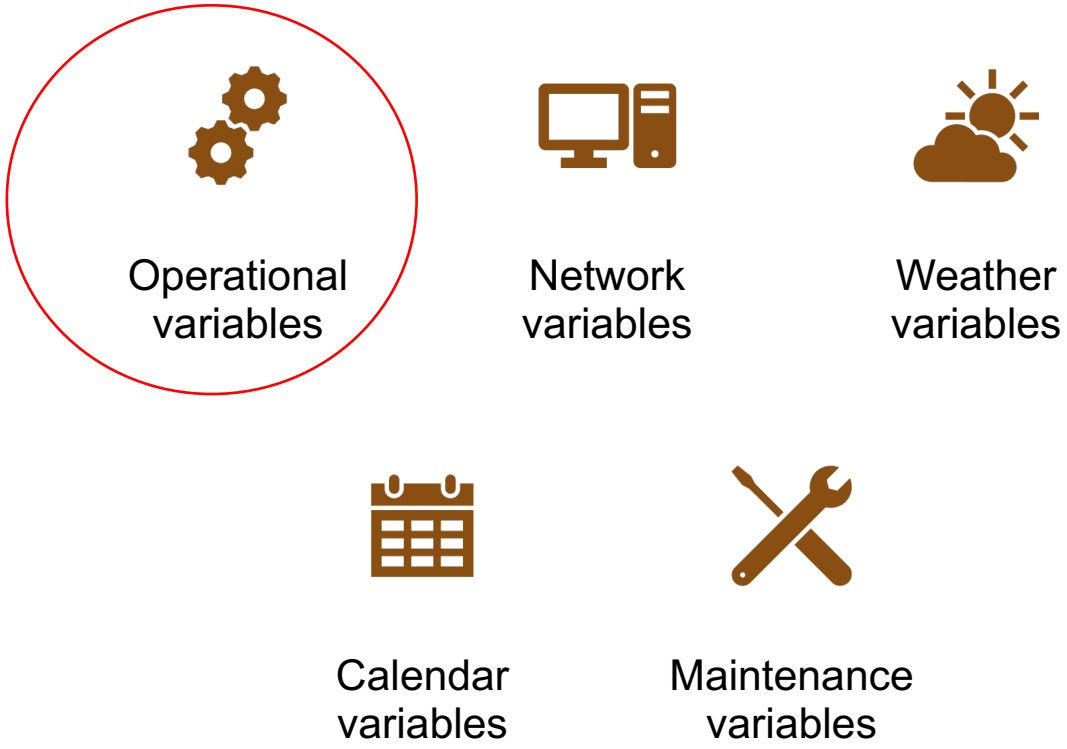

Findings

- The train operation data greatly influences delays.
- Other data adds a layer of adaptability.

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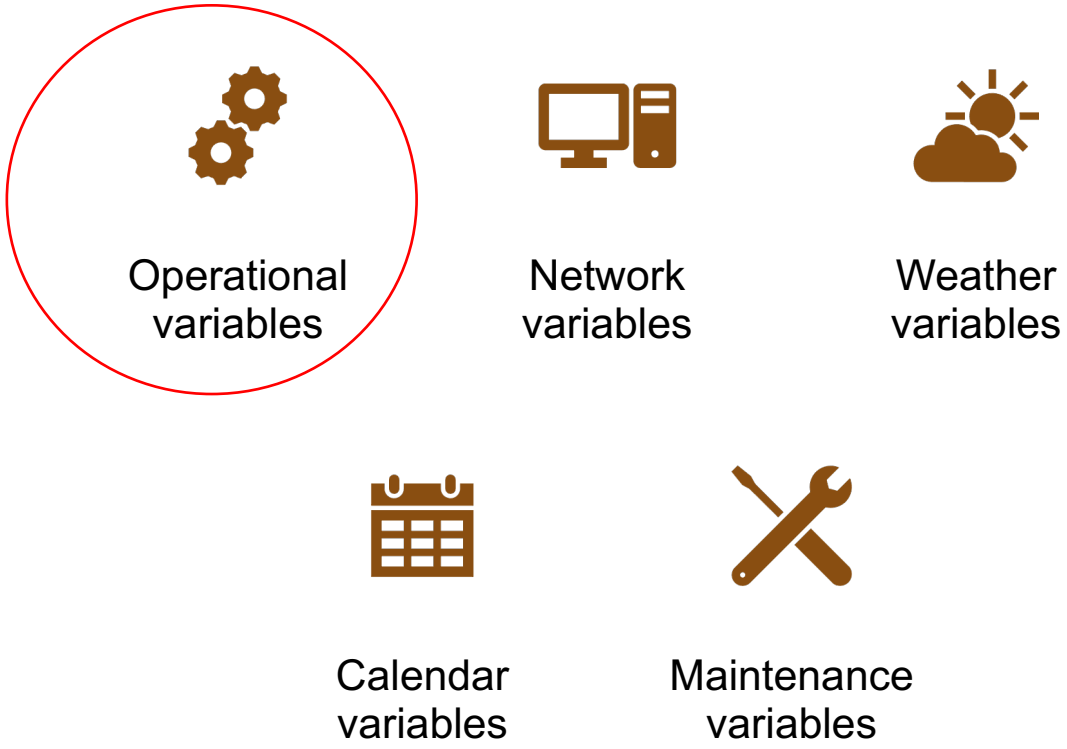

Findings

- The train operation data greatly influences delays.
- Other data adds a layer of adaptability.
- The recent observations from nearby stations or trains are important.

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Research question 3

What approaches can enhance the train delay prediction model?

Location-conditioned concept

$$\hat{y} = f(X|i)$$

where $\hat{y} = (\hat{t}_{i+1}, \hat{t}_{i+2}, \ldots, \hat{t}_N)$, denotes the predicted train arrival delays at subsequent stations given current station *i*. *X* represents a set of predictor variables encompassing both historical and real-time explanatory factors.

Findings

- Regression models trained conditionally on current train location.

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Location-conditioned concept

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Findings

- Regression models trained conditionally on current train location.
- Considers observable real-time and historical data.

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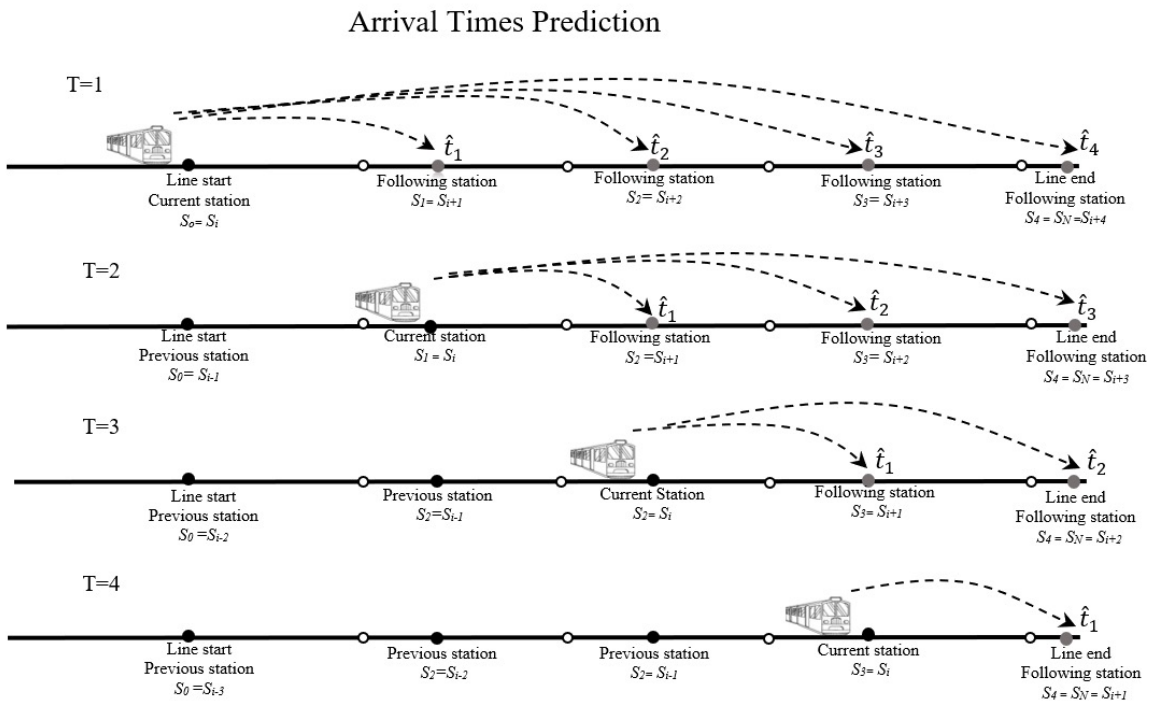
Multi-output framework



- Stop station with observed information
- Stop station with arrival time to be predicted
- Nonstop station

Findings

- Predict arrival delays for multiple downstream stations at arbitrary times.

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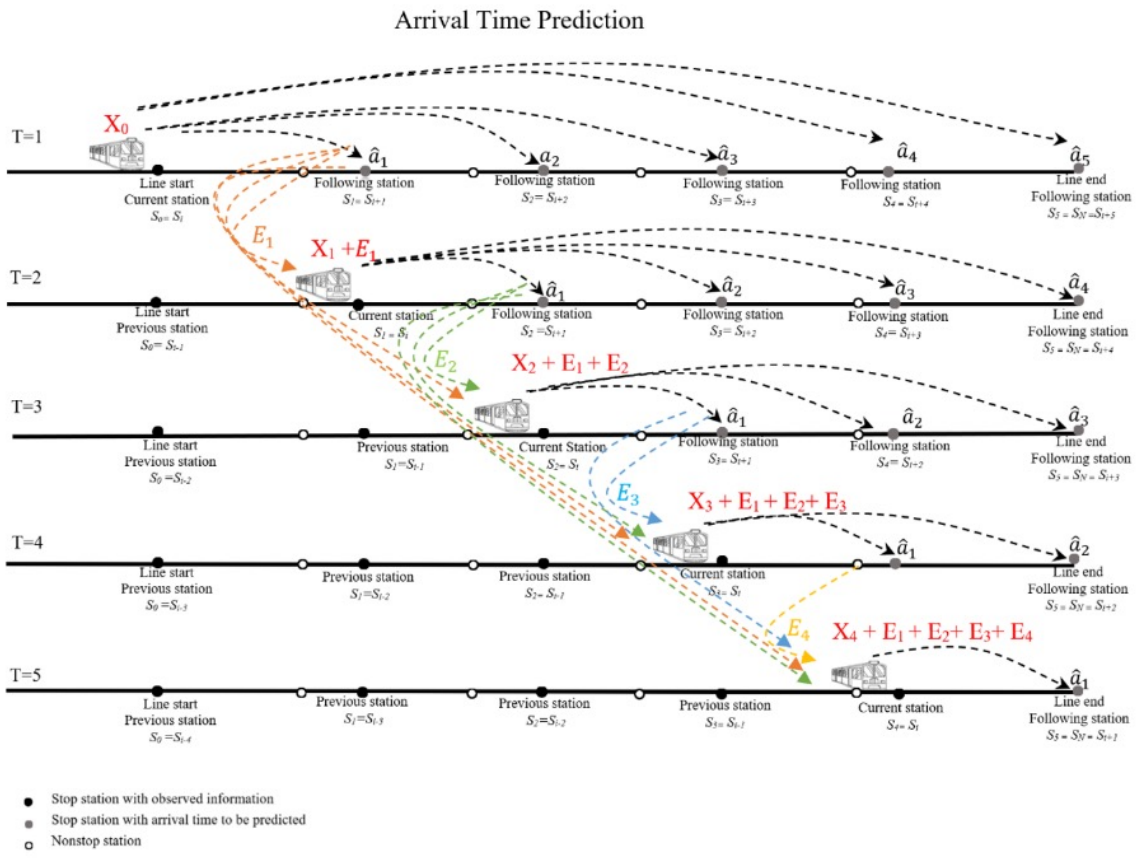
Error adjustment strategies



Upstream prediction error correction

Findings

- Use observed information, prediction errors at current and previous stations.

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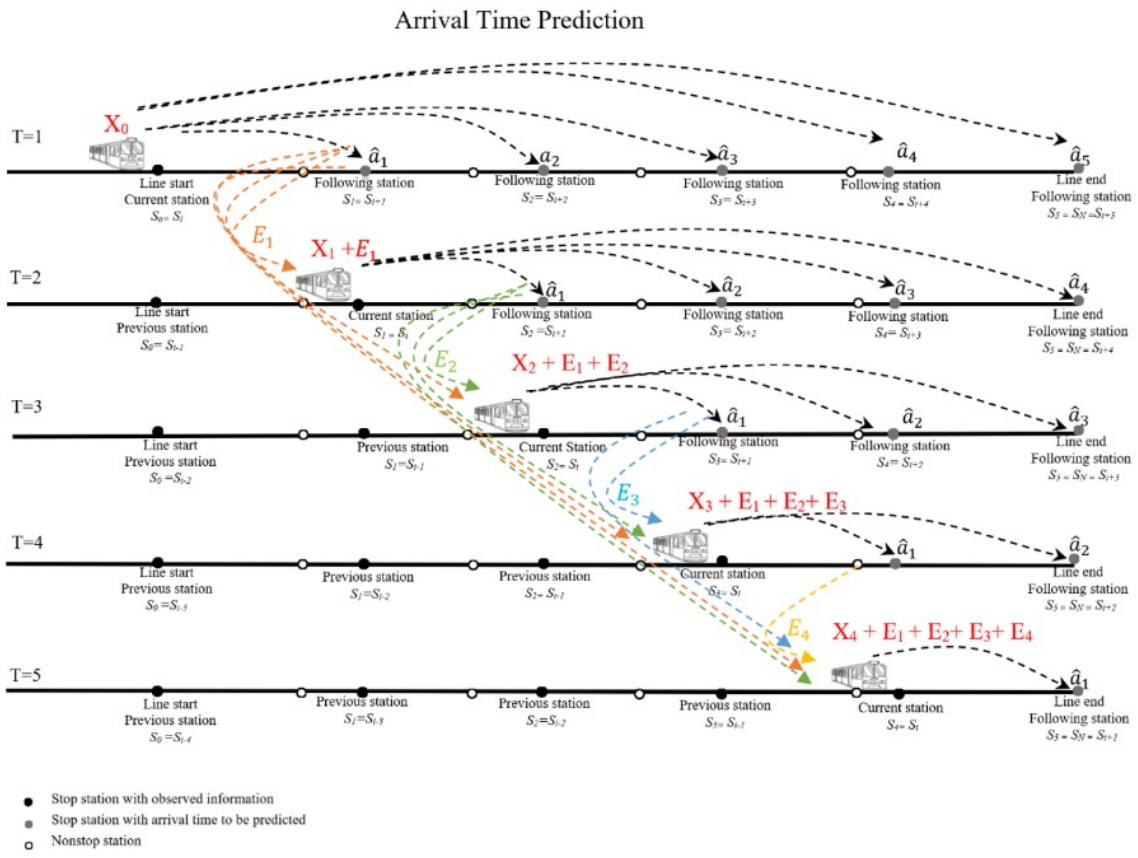
Error adjustment strategies



Upstream prediction error correction

Findings

- Use observed information, prediction errors at current and previous stations.
- Enable the model to constantly adjust itself .

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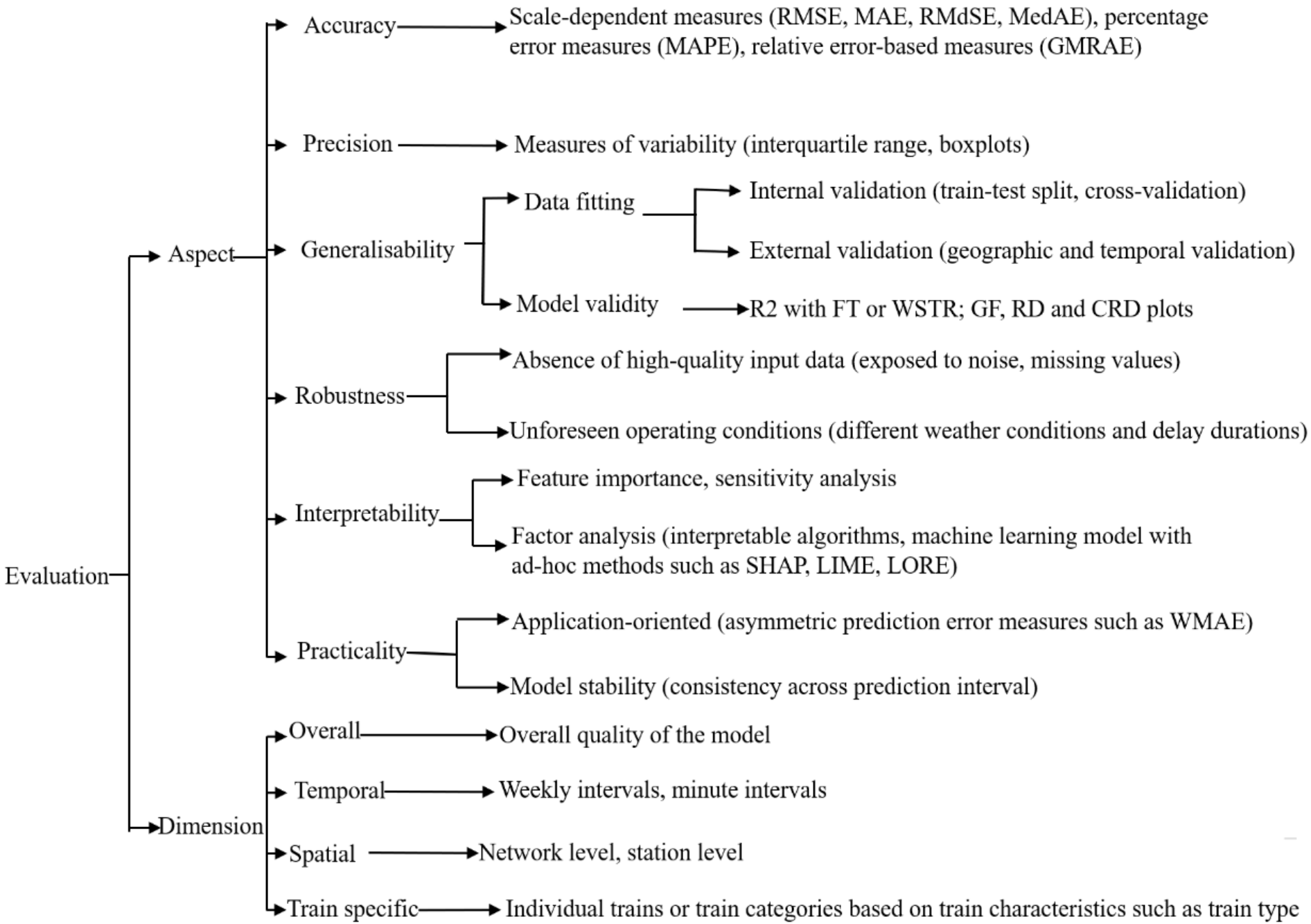
Research question 4

How can train delay prediction models be evaluated?



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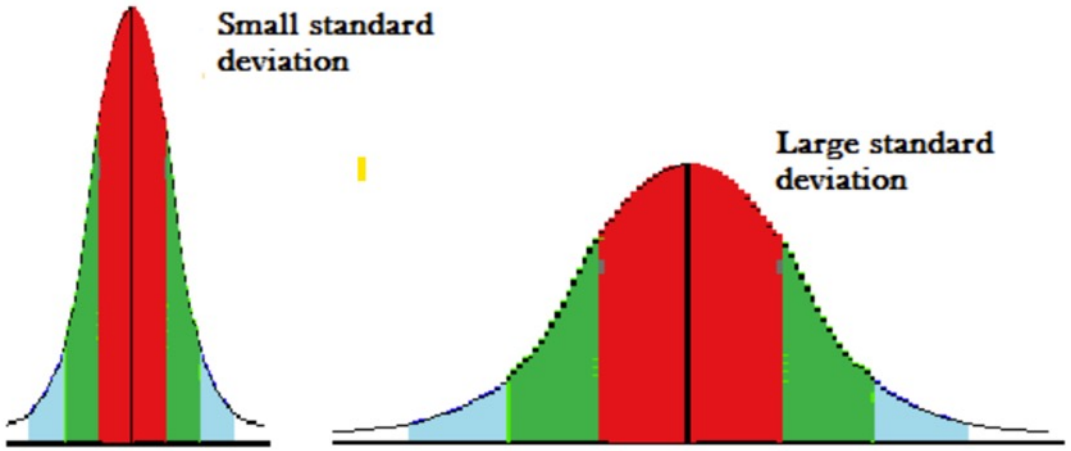
Precision



Statistical variance or the spread of data

Findings

- Measures dispersion of prediction error and bias tendencies.

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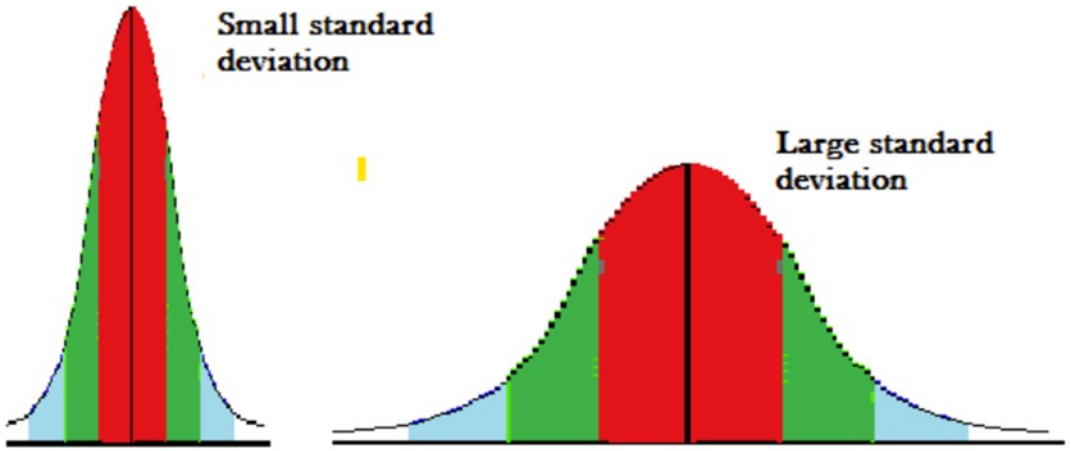
Precision



Statistical variance or the spread of data

Findings

- Measures dispersion of prediction error and bias tendencies.
- The narrower ranges mean more reliable predictions.

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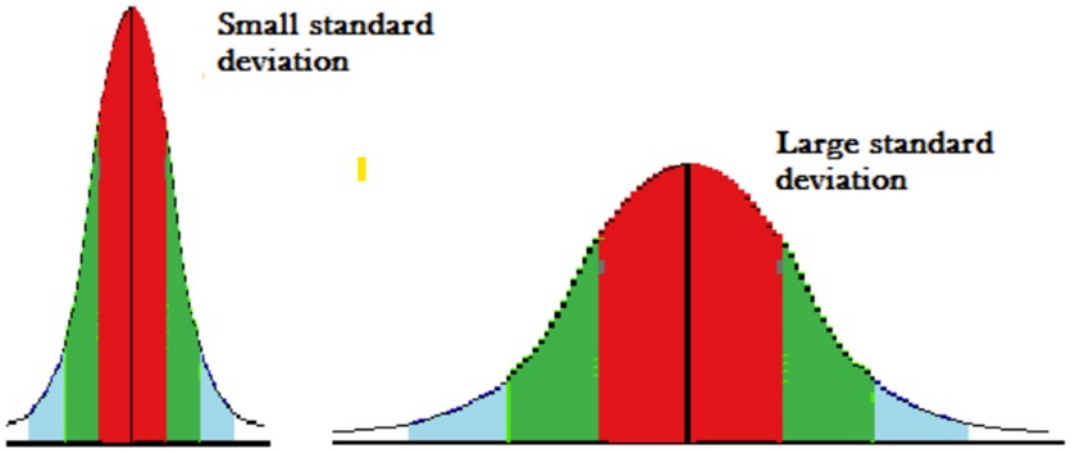

Statistical variance or the spread of data

Findings

- Measures dispersion of prediction error and bias tendencies.
- The narrower ranges mean more reliable predictions.
- The interquartile range or boxplot clarify prediction error uncertainty.

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Robustness

(a) Invalid inputs

Robustness

(a) Invalid inputs

(b) Challenging environmental conditions

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Robustness

Findings

(a) Invalid inputs

(b) Challenging environmental conditions

- Use datasets with realistic representative of real-world application scenarios.

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Robustness

(a) Invalid inputs

(b) Challenging environmental conditions

Findings

- Use datasets with realistic representative of real-world application scenarios.
- Prevent purely academic contributions without real-world industrial use.

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Practicality

(a) Application-oriented

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Practicality

(a) Application-oriented

Findings

- Tolerance for prediction errors varies depending on the model's use case.

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Practicality

(a) Application-oriented

Findings

- Tolerance for prediction errors varies depending on the model's use case.
- Measure using asymmetric prediction error measures

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Practicality

(a) Application-oriented

Departures			03:38:07
Route	Destination	Stop	Time
1	Blackyard leys	R2	~ 5 Min
4A	Wood farm	R7	~ 20 Min
4	Abingdon	R8	~ 40 min
5	Old woodstock	R5	~ 05:10 Pm
7	Aylesbury	R2	~ 05:45 PM
S1	Thornhill park & ride	R6	~06:00 PM
S3	Seacourt park & ride	R1	~06:20 PM

(b) Stability of predictions

Findings

- Tolerance for prediction errors varies depending on the model's use case.
- Measure using asymmetric prediction error measures
- Assesses the consistency of the predictions at each prediction interval .

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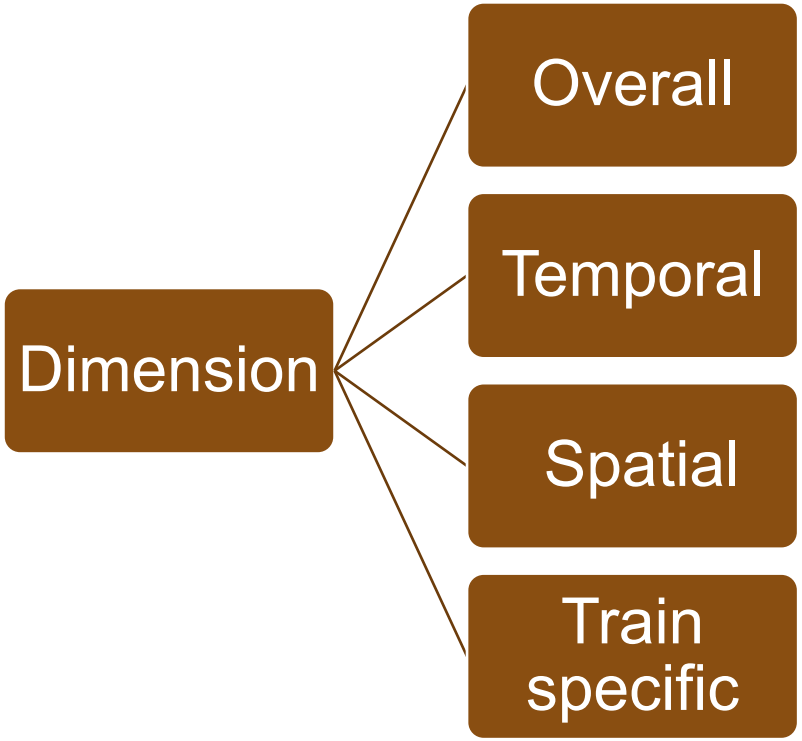
Dimension



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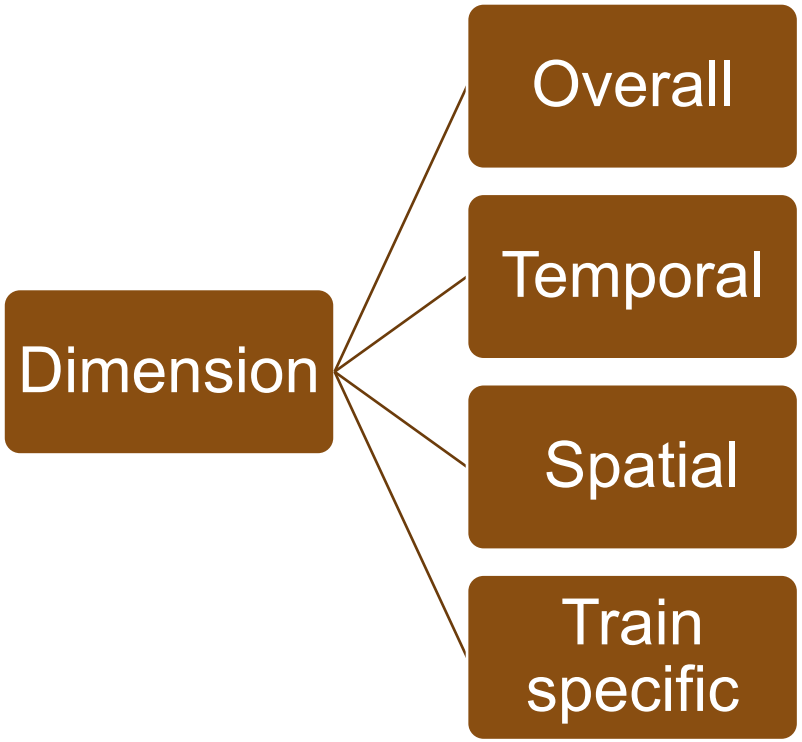
Dimension



Findings

- Overall performance evaluation provides overview of the model's quality.

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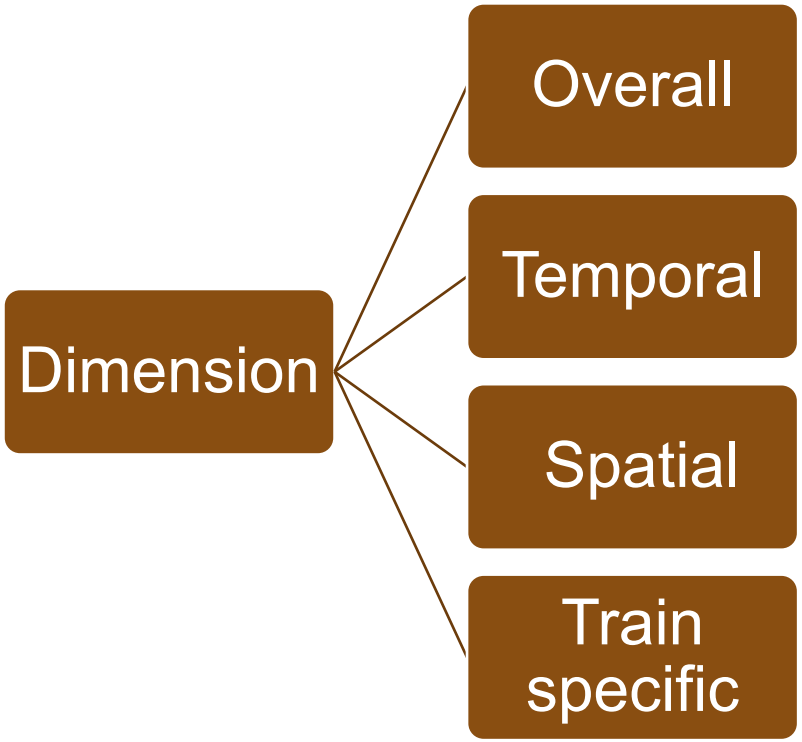
Dimension



Findings

- Overall performance evaluation provides overview of the model's quality.
- Detailed evaluations across dimensions uncover underlying performance patterns.

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Conclusion & Future research

Conclusion

- Use recent data improves train delay prediction model.
  - Introduced location conditional concepts and error adjustment strategies
  - Generate synthetic train events

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Conclusion

- Use recent data improves train delay prediction model.
  - ➢ Introduced location conditional concepts and error adjustment strategies
  - ➢ Generate synthetic train events
- Dynamic multi-output prediction models are crucial for practical applications
  - ➢ Introduced line-level multi-output machine learning models
  - ➢ Network-level prediction models

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Conclusion

- Use recent data improves train delay prediction model.
  - ➢Introduced location conditional concepts and error adjustment strategies
  - ➢Generate synthetic train events
- Dynamic multi-output prediction models are crucial for practical applications
  - ➢Introduced line-level multi-output machine learning models
  - ➢Network-level prediction models
- Evaluate models from various aspects and dimensions
  - ➢Established an evaluation framework
  - ➢Conduct comprehensive case studies

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Thank you!!!

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