Loughborough University

Road Safety and Simulation Conference

Session 6: Big Data

Presenter: Dr Cheuk Ki Man (Jacky)

Paper 185: Exploring Transferability of Real-time Crash Prediction Models using Transfer Learning under Imbalanced Data Setting

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Outline of Presentation

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01 Introduction

02 Literature Review

03 Knowledge Gap

04 Data Collection and Preparation

05 Methodology

06 Results

07 Discussion

08 Limitations and Future Research Directions

1 Introduction

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More than 1.35 million people died annually as a result of road traffic crashes.

- WHO, 2018 -

Works on understanding crash mechanisms began since 1960s.

Conventional Accident Frequency Studies

Real-Time Crash Prediction

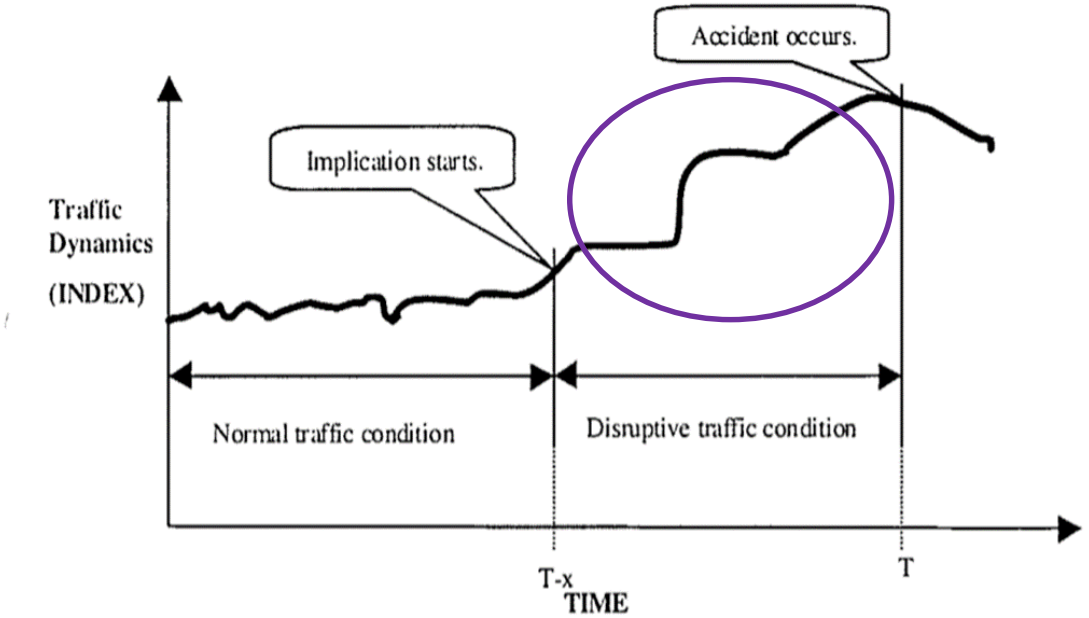

Fig.1 Normal and disruptive traffic dynamics (Oh et al., 2001)

1 Introduction

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Real-Time Crash Prediction

to classify crash from non-crash traffic situations.

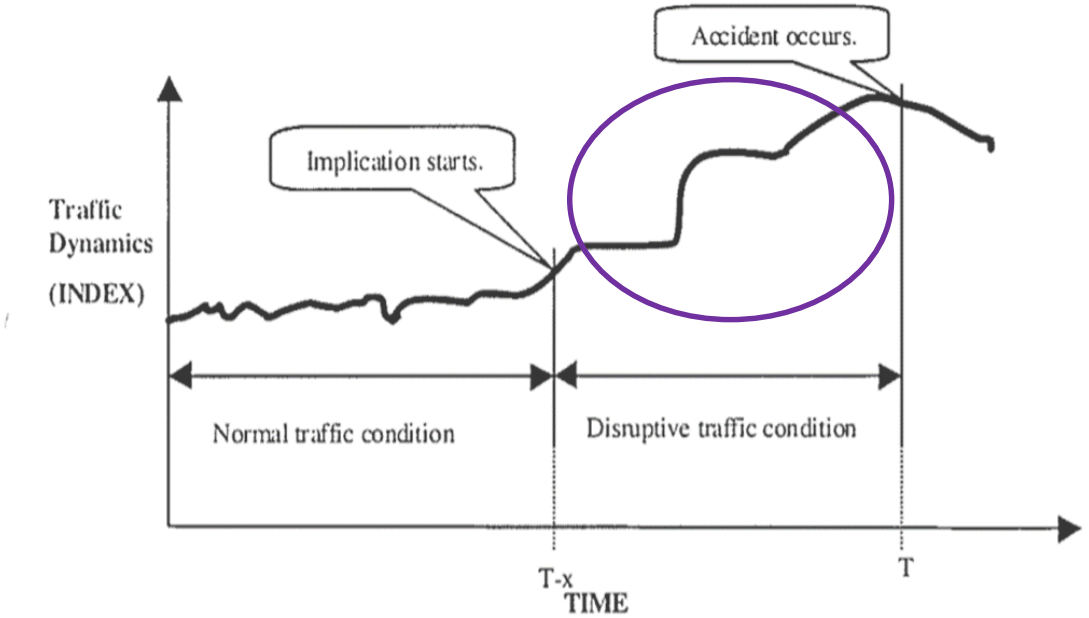

Fig.1 Normal and disruptive traffic dynamics (Oh et al., 2001)

2 Literature Review – Real-time Crash Prediction

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Studied commenced since 1990s with the advocate of **Active Traffic Management System** (a safety paradigm shift from reactive to proactive)

With disaggregated data became available, **real-time crash prediction models** were made feasible.

Common methodology of classify crash from non-crash cases using **matched case-control sampling**.

Models with different **statistical and machine learning methods** were developed.

Use of full-dataset classification in recent studies (**Data imbalance issue**)

Matched case-control sampling

1 Crash : **4** Non-crash

Literature Review – Imbalanced Data Issue

- Crash is **rare** and **stochastic**
- In **traffic data**
  - crash is minority case
  - non crash is majority case
- **Highly Imbalanced Data**
  - Biased Data
  - Prediction will slant on majority case (low recall)
- Data needed to be balanced through **oversampling**
  - balancing crash and non-crash by creating more crash cases synthetically

Non-Crash	Non-Crash	Non-Crash	Non-Crash	Non-Crash	Non-Crash	Non-Crash	Non-Crash
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Literature Review – Transferability

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Transferability is:

"ability of the model or the findings of one sample to be applied to another sample"

- Polit and Beck, 2010 -

Conventional Approach

- Direct testing and updating approach

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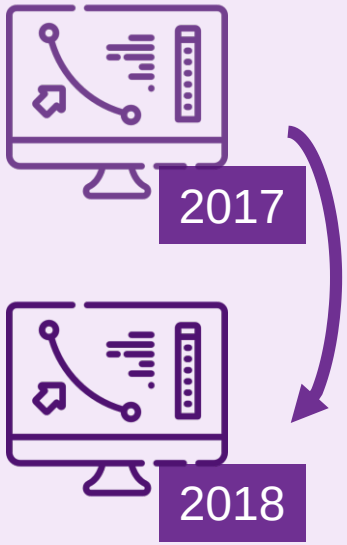
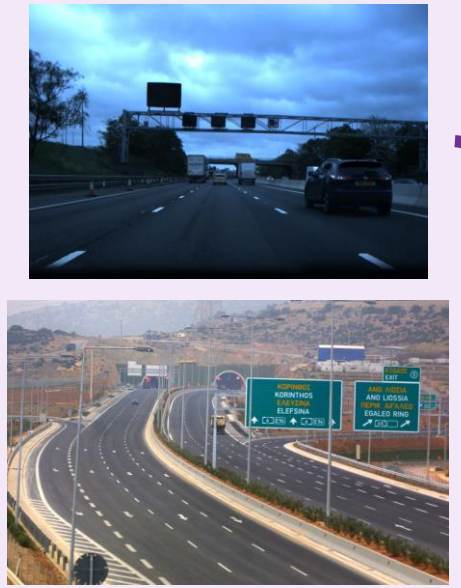
Limited model transferability

3 types of transferability modes:

1 Temporal Transfer



2 Spatial Transfer



3 Spatio-Temporal Transfer

3 Knowledge Gap

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Class Imbalance

- Heavily imbalanced disaggregated traffic data
- Oversampling for class balancing (i.e. WGAN)

Aim

To develop a **transferable** real-time crash prediction model using **highly imbalanced** disaggregated real-time traffic data

Model Transferability

- Limited model transferability
- Transfer Learning

4 Data Collection and Preparation

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Accident Data + Minute-Level Traffic Data + Loop Detector Data

Data integration, matching, cleansing, aggregation

Real-time imbalanced traffic dataset + **Synthetic Data**

Dataset for Real-time Crash Prediction Models

6 Datasets

Study Area: M1, M4, M6 | Data: 2017 and 2018

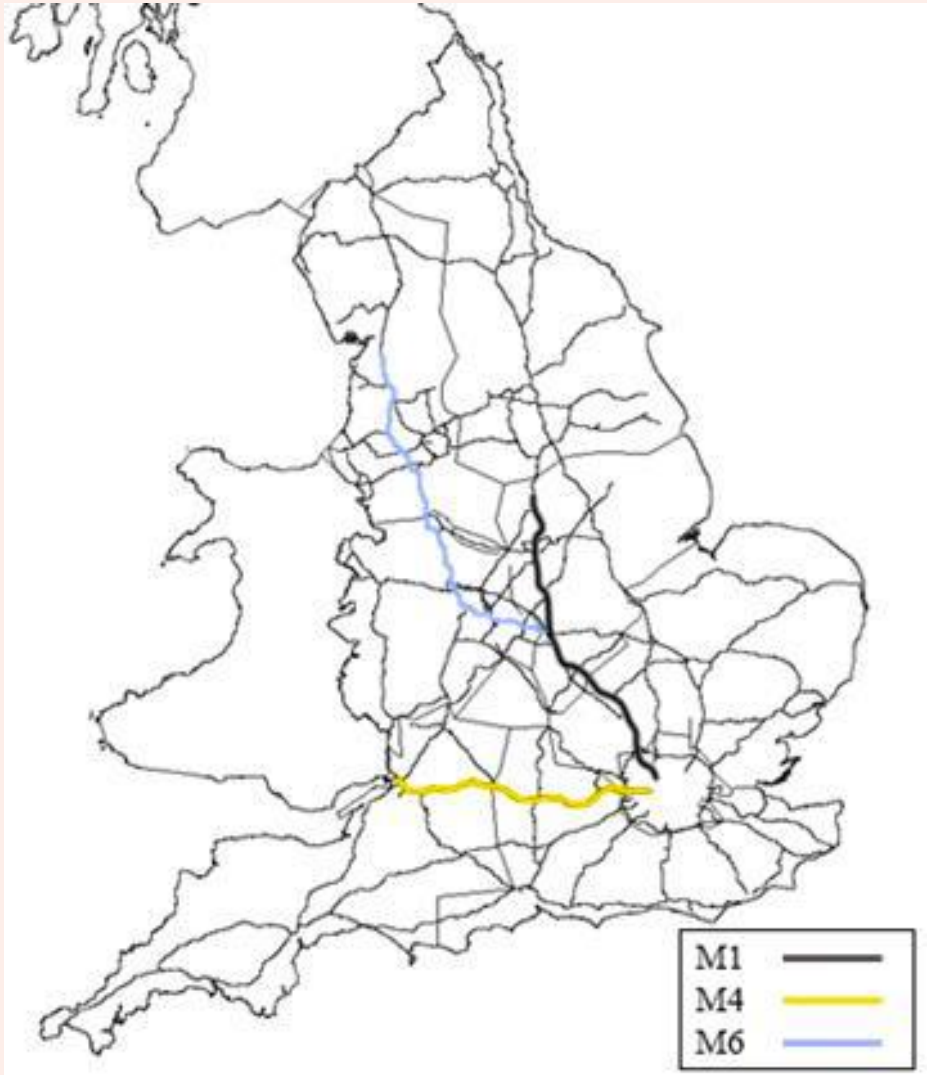

Figure 2. Study Area

5 Methodology - Experimental Framework

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This experiment is conducted as follow:

Prepare and Cleanse Data 01

Balance Dataset with WGAN 02

Develop Baseline Model and Standalone models using DNN 03

Compare transferability performances 04

- Through transfer learning, direct model testing and standalone models

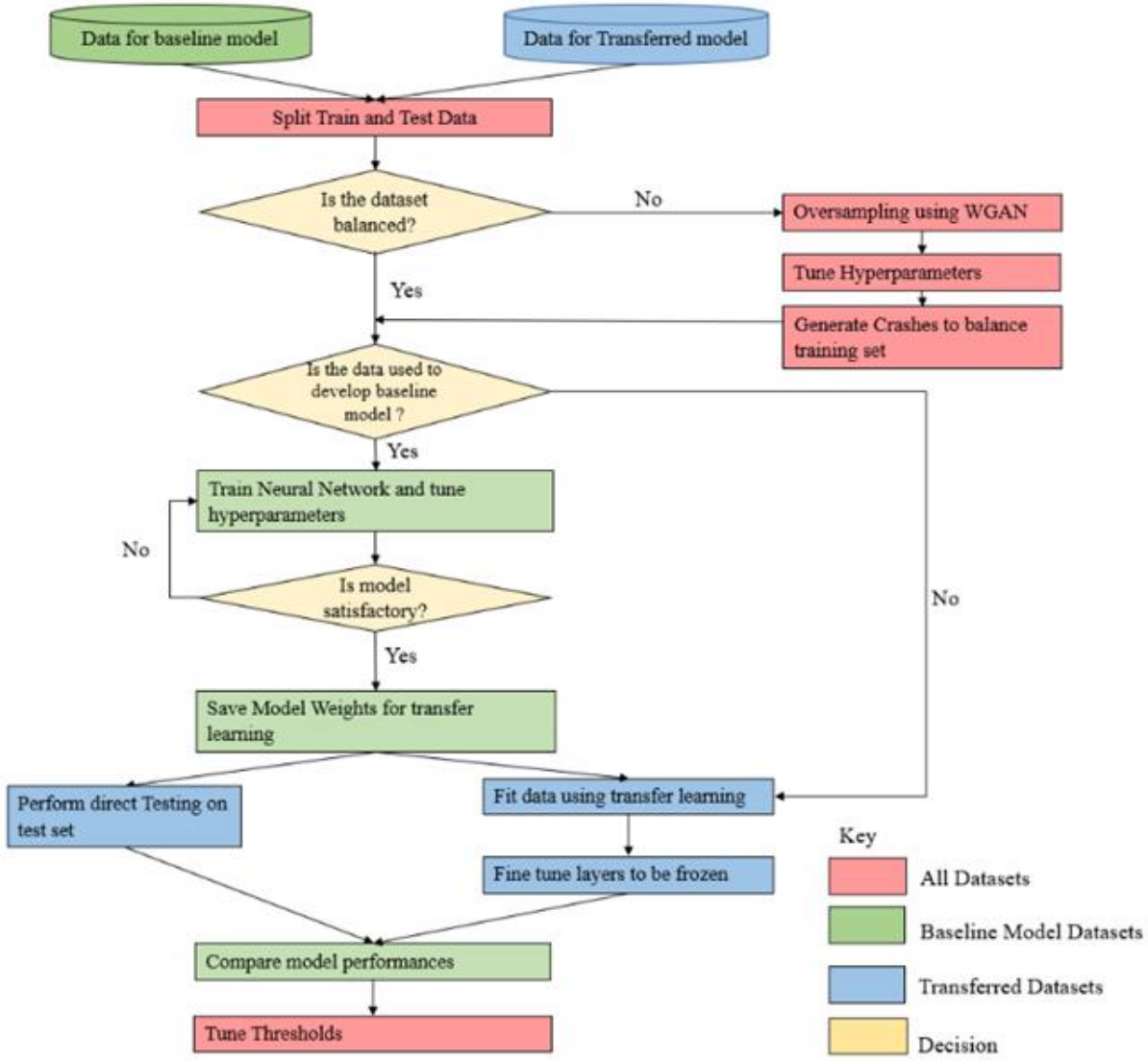

Figure 3. Flowchart of Current Study

Methodology - Wasserstein GAN

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- Concept from the generator learns from the feedback of the critic network who tells if the **synthetic data generate is good or bad**.
- A **variant** of GAN
- Generative model for synthetic data
- **Better training quality** than GAN

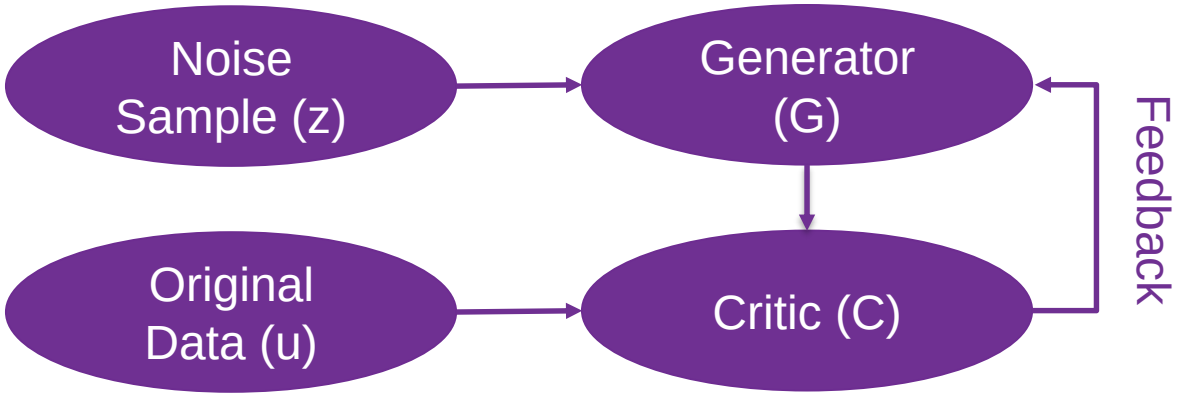

Figure 4. WGAN Architecture

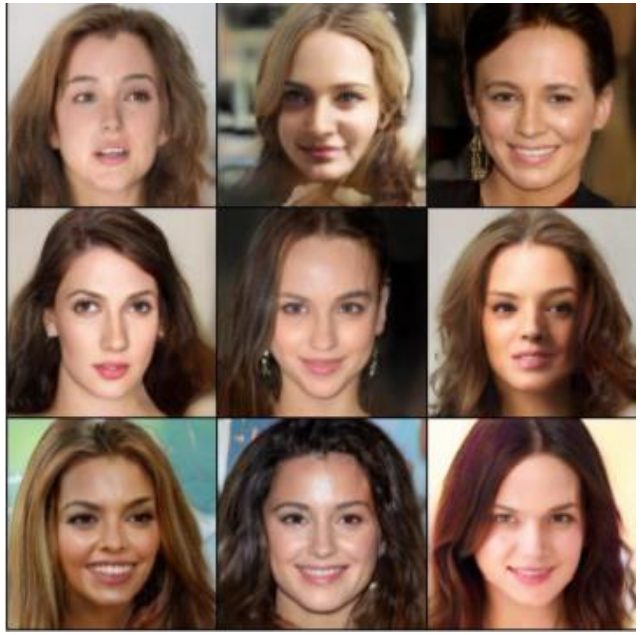

Figure 5. Example of synthetic images generated from WGAN (adopted from Liu et al., 2019)

5 Methodology - Transfer Learning

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- Employed in **computer science**
  - E.g. translation software, word character recognition
- Fitting the weights trained from the source model (M1 2017) to dataset to be transferred
- Layers can be **fine tuned** customising hidden layers to be frozen

Figure 5. Transfer Learning Procedure

Methodology - Deep Neural Network

- **DNN** is used as real-time crash prediction model
- Ability to learn **large datasets** in a non-linear manner
- High model predictability in literature

Figure 6. Architecture of Deep Neural Network

6 Findings – Transfer Learning vs Direct Testing

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- Transfer Learning was applied
- Weights trained from M1 2017 model was applied to 5 other datasets with fine tuning performed
- Best performance in temporal transfer with **0.95 AUC**
- Direct Testing does not work

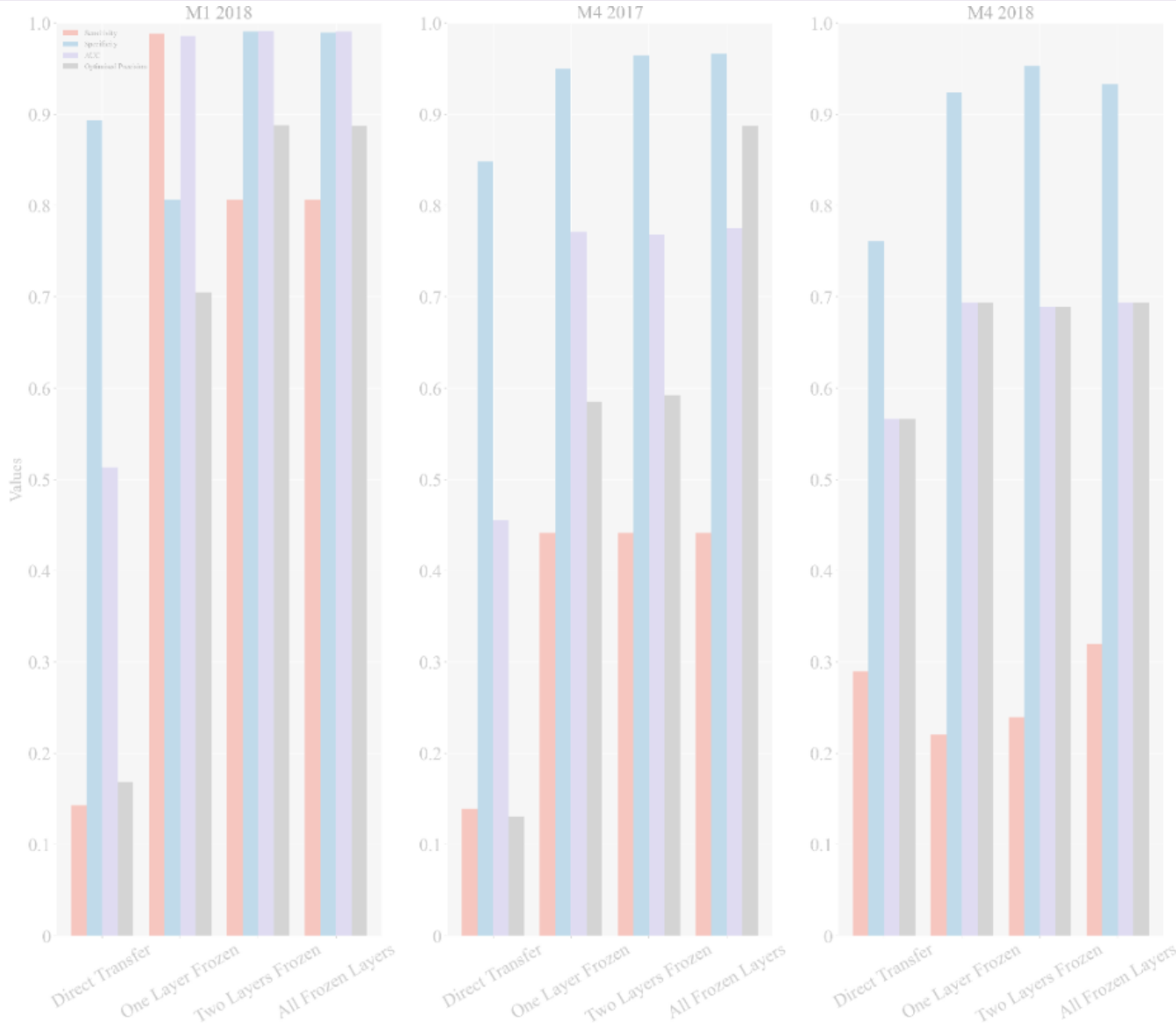

Figure 7. Examples of Results between Direct Testing and Transfer Learning

6 Findings – Transfer Learning vs Standalone Models

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- **Five** separate standalone models trained for comparison
- Transfer Learning achieved even **better performance** than standalone models

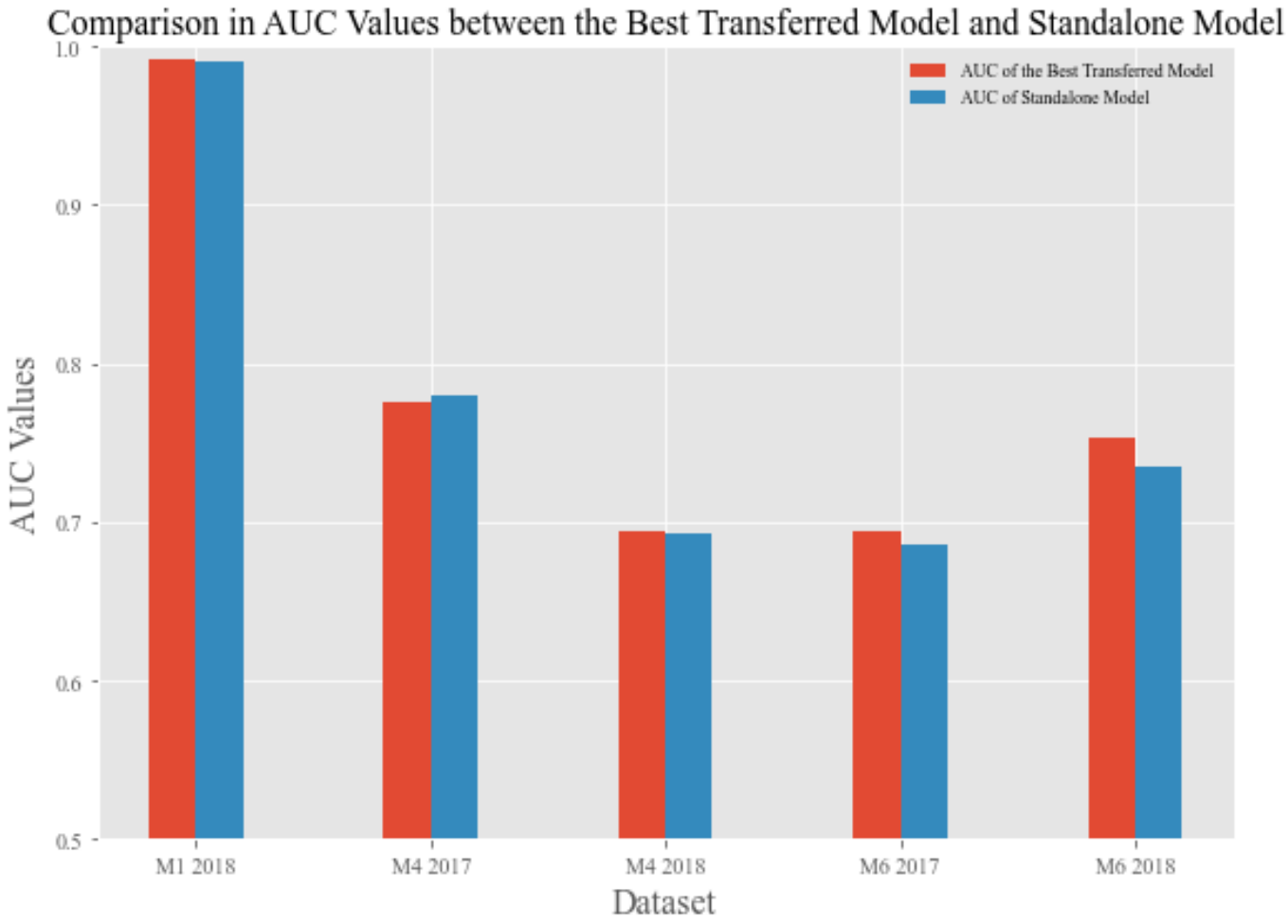

Figure 8. Comparison of Model Performance between Best Transferred Model and Standalone Model

7 Discussion

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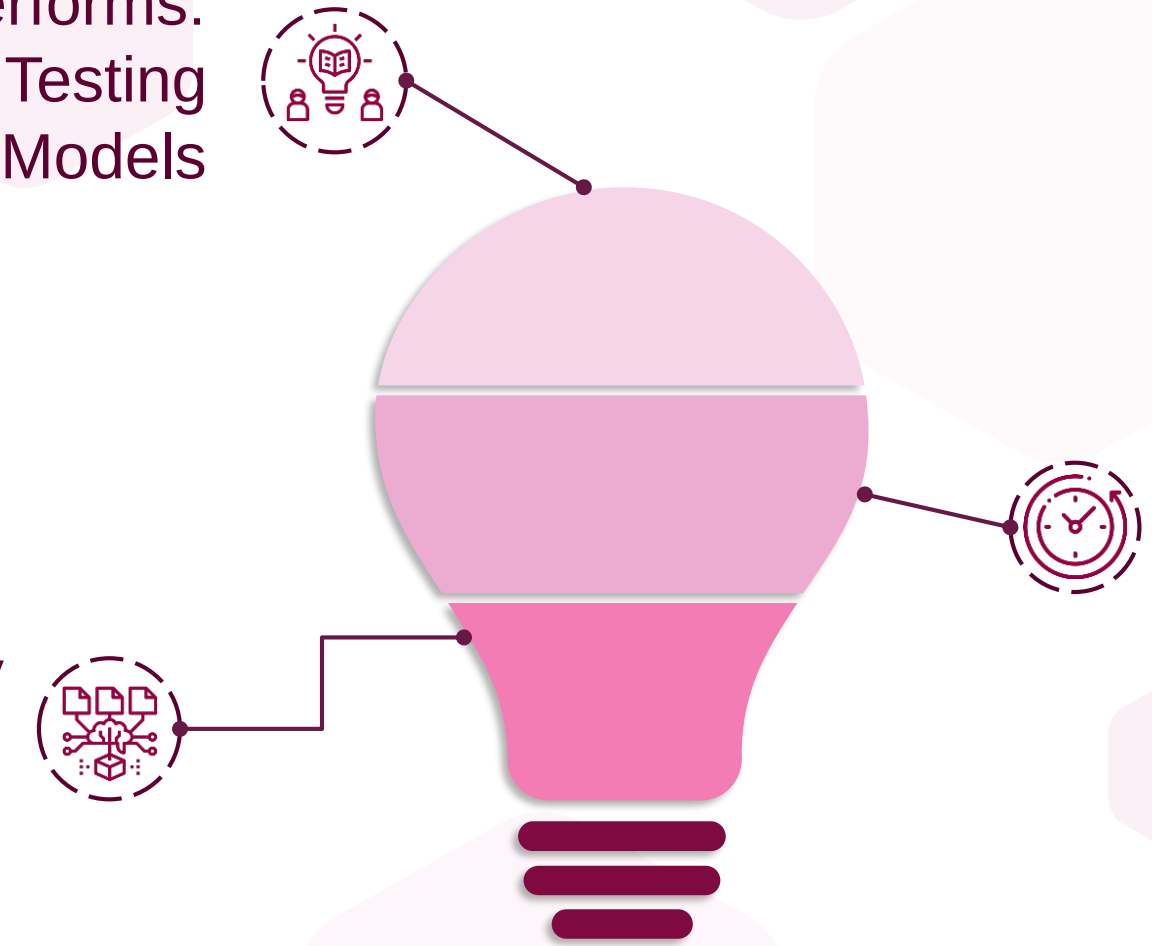
Transfer Learning Outperforms:

- Direct Testing
- Standalone Models



Can save time and effort for tuning and training hyperparameters for different models

Easier for highway managers to deploy real time crash prediction model

Limitations + Future Research Directions

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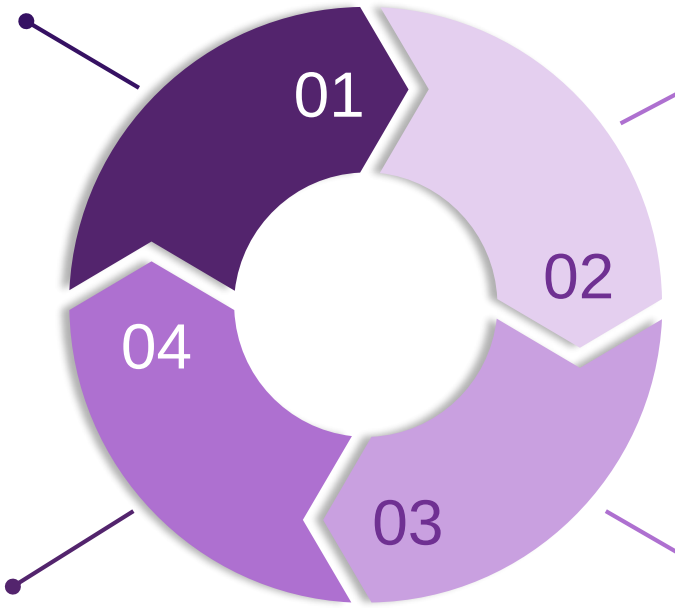
Use of Large Datasets in future



Inclusion of data from various dataset in model transferability

Use of different ML/AI models for transferability test

Test the minimum amount of data required for model transfer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Thank You !
Any Questions?