

# The Weather Impact on Travel Behavior in Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.northwestern.edu

Department of Statistics  
Northwestern University

Internship at CMAP Apr. - Jun. 2011

October 8, 2012

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Outline

## Introduction

## Background

The Travel Tracker Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip Generation Model  
Weather Adjustment Factor

## Summary

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

## Introduction

## Background

The Travel Tracker  
Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Motivation

- ▶ The travel behavior under good weather conditions has been well studied, and estimation models have been built correspondingly.
- ▶ However, if the model does not consider the weather impact, then it will fail to predict the traffic flow under adverse weather.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Weather Impact Evidence

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

[Introduction](#)

[Background](#)

The Travel Tracker  
Survey  
Weather Data

[Weather Impacts  
on travel behavior](#)

Temperature  
Snowfall  
Snow on Ground  
Rain

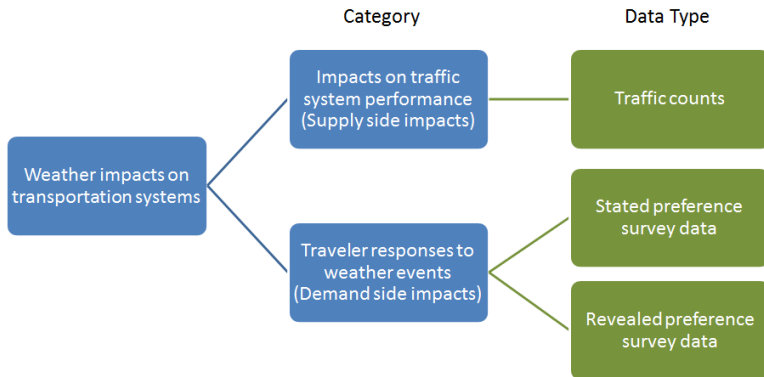
[Modeling Weather  
Impacts on Trip  
Generation](#)

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

**Table:** Responses from the Questionnaire

| Household Number | County | Survey Date        | Response                                           | Weather Info.                                          |
|------------------|--------|--------------------|----------------------------------------------------|--------------------------------------------------------|
| 4040873          | LAKE   | 02/05/07           | "Cold weather"                                     | Temperature Ave. - 7 F, Min. -14 F                     |
| 4038576          | DUPAGE | 02/06/07, 02/07/07 | "The snow changed a lot of plans"                  | Snowfall 3 inches on Feb. 7                            |
| 4131511          | COOK   | 03/23/07           | "Rain"                                             | Rainfall 0.16 inches.                                  |
| 4206622          | COOK   | 07/08/07           | "Too hot to travel"                                | Temperature Ave. 84 F, Max. 93 F                       |
| 4673252          | COOK   | 12/05/07           | "The weather too severe and couldn't do anything." | Snowfall 2.2 inches                                    |
| 4502617          | COOK   | 12/05/07, 12/06/07 | "There was an ice storm."                          | Snowfall 2.2 inches on Dec. 5 and 0.6 inches on Dec. 6 |
| 4578653          | KANE   | 12/11/07           | "The weather caused the change."                   | Snowfall 0.2 inches                                    |

# Literature Review



The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Study Based on Traffic Volume on Road

- ▶ Al Hassan and Barker (1999): Average traffic reduction of 10% on weekday and 15% on weekends when snow was lying on the ground. (Data: Scotland 1987 ~ 1991)
- ▶ Keay and Simmonds (2005): Statistically significant reduction of 1.35% and 2.11% in traffic volume on wet days in winter and spring. (Data: Melbourne, Australia, 1989 ~ 1996)
- ▶ Maze et. al. (2005): On snowy days, wind speed and visibility are influencing factors on traffic volume. (Data: Northern Iowa 2000 ~ 2001)
- ▶ Other studies: Chung et al. (2005), Hanbali and Kuemmel (1993), etc.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

## Introduction

### Background

The Travel Tracker  
Survey  
Weather Data

### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Study Based on Survey Data

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

## Stated Preference Study

- ▶ Khattak and De Palma (1997): 54% of automobile users would change their mode, departure time and/or route choices in response to weather conditions. Ordered probit models are used to investigate the effect of weather on mode and departure time. (Data: Brussels 1992)
- ▶ Bergstrom and Magnusson (2003): The number of car trips increased by 27% from summer to winter while the number of bicycle trips decreased by 47%. (Data: Sweden, 1998, 2002)

**Shortcoming:** Stated preference data may not represent actual behaviors.

# Study Based on Survey Data

## Revealed Preference Study

- ▶ Aaheim and Hauge (2005): A quantal response model was employed to model the choice of transport mode. The number of walk and bike trips increases with the temperature, but the number of private automobile trips has the opposite relation with the temperature. (Data: Bergen, Norway 2000)
- ▶ Khattak (1991): On one blizzard afternoon, more than 80% of the respondents changed one or more of their normal mode, route and departure times on their return trip from work. (Data: Chicago)
- ▶ Sabir et al. (2008): A multinomial logit model is used to analyze the impact of weather conditions on mode choice. Strong winds and low temperatures decrease bicycle use and stimulate the use of the car and public transport. (Data: Netherland)

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

## Introduction

### Background

The Travel Tracker  
Survey  
Weather Data

### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Framework of This Study

- ▶ Studying and testing weather impacts on travel behavior.
  1. Weather factor: temperature, snowfall, snow lying on ground, and rain.
  2. Travel behavior: trip rates, trip distance, and trip duration.
- ▶ Modeling weather impacts on trip generation.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

## Introduction

### Background

The Travel Tracker  
Survey  
Weather Data

### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Outline

## Introduction

## Background

The Travel Tracker Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip Generation Model  
Weather Adjustment Factor

## Summary

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

### Introduction

### Background

The Travel Tracker  
Survey  
Weather Data

### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# The Travel Tracker Survey

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

- ▶ Coverage: 8 counties in northeastern Illinois - Cook, DuPage, Grundy, Kane, Kendall, Lake, McHenry, and Will.
- ▶ Time: January 2007 and February 2008
- ▶ Sample size: 10,552 households.
- ▶ Survey type: 6175 households took part in a 1-day survey and the other took part in a 2-day survey.
- ▶ Information gathered: (1) Demographic information; (2) Detailed travel records.

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Weather Data

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

- ▶ Source: National Oceanic and Atmospheric Administration (NOAA).
- ▶ There are 36 weather stations spread within these 8 counties considered.
- ▶ One weather station is selected for each county and its weather data is used for this study.

Introduction

Background

The Travel Tracker  
Survey

Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall

Snow on Ground

Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model

Weather Adjustment  
Factor

# Weather Data

## Weather Stations



The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey

Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall

Snow on Ground

Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model

Weather Adjustment  
Factor

# Outline

## Introduction

## Background

The Travel Tracker Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip Generation Model  
Weather Adjustment Factor

## Summary

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

### Introduction

### Background

The Travel Tracker  
Survey  
Weather Data

### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Overview

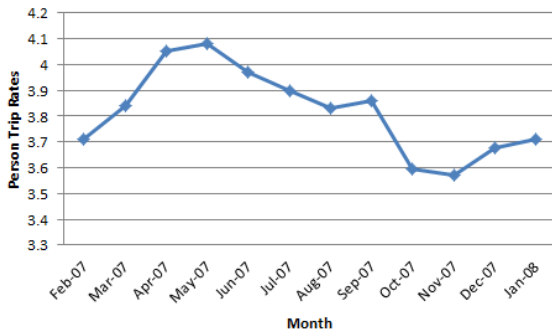


Figure: PERSON TRIP RATES BY MONTH

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Overview

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

- ▶ This monthly plot reflects the impact of multiple weather factors.
- ▶ Next, we study the impact of temperature, snowfall, snow on ground, and rain separately.

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

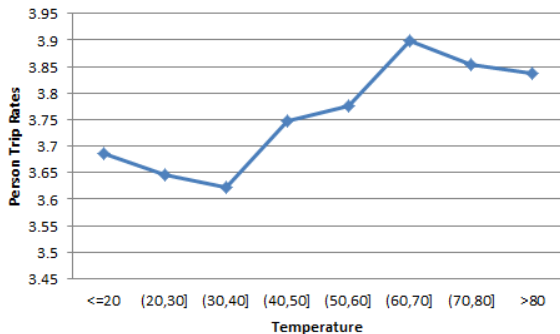
**Weather Impacts  
on travel behavior**

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Temperature



**Figure:** PERSON TRIP RATES BY DAILY AVERAGE TEMPERATURES

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall

Snow on Ground

Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model

Weather Adjustment  
Factor

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

## Observation

- ▶ Generally speaking, when the temperature went up, people tended to make more trips.
- ▶ When daily average temperature goes up above 70 F, people tend to make fewer trips.
- ▶ During days with extreme low temperature, people seemed to make a few more trips.

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall

Snow on Ground

Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Question:

**Why did people make a few more trips in extremely cold weather?**

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

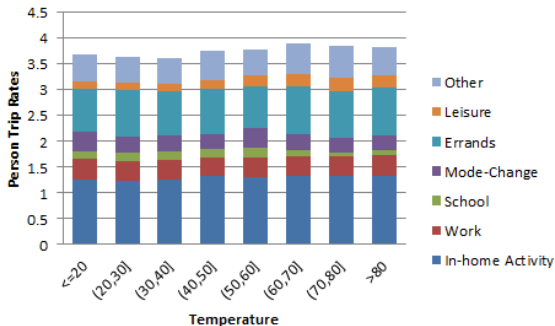
**Temperature**

Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Temperature



**Figure:** PERSON TRIP RATES BY DAILY AVERAGE TEMPERATURES AND TRAVEL PURPOSES

Under extremely cold weather, people would make more trips for passenger pick-up/drop-off/mode-change purpose.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall

Snow on Ground

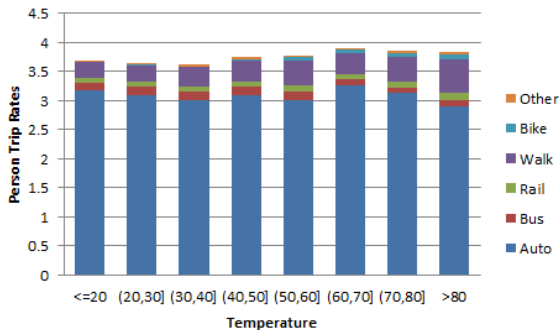
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model

Weather Adjustment  
Factor

# Temperature



**Figure:** PERSON TRIP RATES BY DAILY AVERAGE TEMPERATURES AND TRAVEL MODES

Under extremely cold weather, people tended to use private auto vehicles, instead of walking or riding bus.

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

**Why did people make a few more trips in extremely cold weather?**

## Example

- ▶ On regular days, person A went to work by auto and person B went to school by walking separately.
- ▶ On cold days, person A would give person B a ride to school, in which case, there would be 2 trips counted for A (including 1 passenger pick-up/drop-off/mode-change trip), and 1 trip counted for B.

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall

Snow on Ground

Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

## Statistical tests

- ▶ Classify days into cold days (Temperature  $< 60\text{F}$ ) and warm days (Temperature  $\geq 60\text{F}$ ).
- ▶ Study and test the change of travel behavior for different groups of people.
- ▶ For each hypothesis test, three test methods are performed: Wilcoxon rank-sum test, two sample t-test, and two-sample z-test. The testing results are consistent. For simplicity, only the t-test results are displayed.

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

Table 2: PERSON TRIP RATES BY TEMPERATURE

| Variable          | Category | Sample Mean<br>(Temp.<60F) | Sample Mean<br>(Temp.>=60F) | Decrease<br>(%) | Significance<br>(level 0.05) |
|-------------------|----------|----------------------------|-----------------------------|-----------------|------------------------------|
| Age               | <20      | 3.10                       | 3.31                        | 6.38            | S                            |
|                   | 20-24    | 3.36                       | 3.31                        | -1.39           | I                            |
|                   | 25-54    | 4.09                       | 4.29                        | 4.57            | S                            |
|                   | 55-64    | 3.95                       | 4.12                        | 4.04            | S                            |
|                   | 65+      | 3.40                       | 3.53                        | 3.70            | S                            |
| Gender            | Male     | 3.62                       | 3.78                        | 4.29            | S                            |
|                   | Female   | 3.76                       | 3.94                        | 4.68            | S                            |
| License<br>Status | Yes      | 4.06                       | 4.16                        | 2.38            | S                            |
|                   | No       | 2.18                       | 2.32                        | 5.89            | S                            |
| Worker<br>Status  | Yes      | 4.13                       | 4.27                        | 3.19            | S                            |
|                   | No       | 3.27                       | 3.43                        | 4.67            | S                            |
| Day               | Weekday  | 3.74                       | 3.93                        | 4.72            | S                            |
|                   | Weekend  | 3.27                       | 3.56                        | 8.15            | S                            |

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

| Variable | Category        | Sample Mean<br>(Temp.<60F) | Sample Mean<br>(Temp.>=60F) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|----------------------------|-----------------------------|-----------------|------------------------------|
| Mode     | Auto            | 3.07                       | 3.16                        | 2.84            | S                            |
|          | Bus             | 0.15                       | 0.10                        | -43.12          | S                            |
|          | Rail            | 0.09                       | 0.10                        | 11.78           | S                            |
|          | Walk            | 0.34                       | 0.42                        | 18.10           | S                            |
|          | Bike            | 0.02                       | 0.06                        | 67.96           | S                            |
|          | Other           | 0.03                       | 0.03                        | -4.46           | I                            |
| Purpose  | Home            | 1.27                       | 1.32                        | 3.78            | S                            |
|          | Work            | 0.39                       | 0.38                        | -2.52           | I                            |
|          | School          | 0.16                       | 0.10                        | -56.42          | S                            |
|          | Mode-<br>change | 0.33                       | 0.29                        | -14.67          | S                            |
|          | Errands         | 0.86                       | 0.92                        | 7.22            | S                            |
|          | Leisure         | 0.17                       | 0.24                        | 30.22           | S                            |
|          | Other           | 0.51                       | 0.61                        | 15.12           | S                            |
| TOTAL    |                 | 3.69                       | 3.87                        | 4.49            | S                            |

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

Table 3: AVERAGE TRIP DISTANCE BY TEMPERATURE

| Variable | Category        | Sample Mean<br>(Temp.<60F) | Sample Mean<br>(Temp.>=60F) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|----------------------------|-----------------------------|-----------------|------------------------------|
| Mode     | Auto            | 5.21                       | 5.53                        | 5.83            | S                            |
|          | Bus             | 3.55                       | 4.25                        | 16.30           | S                            |
|          | Rail            | 14.66                      | 14.80                       | 1.01            | I                            |
|          | Walk            | 0.91                       | 1.17                        | 21.59           | S                            |
|          | Bike            | 1.92                       | 2.32                        | 17.22           | S                            |
|          | Other           | 11.17                      | 12.19                       | 8.39            | I                            |
| Purpose  | Home            | 5.09                       | 5.45                        | 6.58            | S                            |
|          | Work            | 8.45                       | 8.20                        | -3.05           | I                            |
|          | School          | 3.20                       | 3.91                        | 18.08           | S                            |
|          | Mode-<br>change | 4.38                       | 5.13                        | 14.64           | S                            |
|          | Errands         | 4.26                       | 4.34                        | 1.94            | I                            |
|          | Leisure         | 4.21                       | 4.84                        | 12.98           | S                            |
|          | Other           | 4.69                       | 4.96                        | 5.51            | S                            |
| TOTAL    |                 | 5.02                       | 5.29                        | 5.10            | S                            |

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

Table 4: AVERAGE TRIP DURATION BY TEMPERATURE

| Variable | Category        | Sample Mean<br>(Temp.<60F) | Sample Mean<br>(Temp.>=60F) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|----------------------------|-----------------------------|-----------------|------------------------------|
| Mode     | Auto            | 19.51                      | 20.40                       | 4.38            | S                            |
|          | Bus             | 37.32                      | 35.95                       | -3.80           | I                            |
|          | Rail            | 60.84                      | 64.36                       | 5.47            | S                            |
|          | Walk            | 12.82                      | 14.13                       | 9.23            | S                            |
|          | Bike            | 20.65                      | 22.97                       | 10.06           | I                            |
|          | Other           | 92.37                      | 94.97                       | 2.74            | I                            |
| Purpose  | Home            | 22.15                      | 22.35                       | 0.93            | I                            |
|          | Work            | 29.54                      | 28.94                       | -2.06           | I                            |
|          | School          | 18.23                      | 18.60                       | 1.95            | I                            |
|          | Mode-<br>change | 17.10                      | 19.39                       | 11.84           | S                            |
|          | Errands         | 18.07                      | 18.03                       | -0.24           | I                            |
|          | Leisure         | 20.12                      | 23.99                       | 16.14           | S                            |
|          | Other           | 21.61                      | 23.13                       | 6.56            | S                            |
| TOTAL    |                 | 21.19                      | 21.87                       | 3.12            | S                            |

# Temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

Table 4: AVERAGE TRIP DURATION BY TEMPERATURE

| Variable | Category        | Sample Mean<br>(Temp.<60F) | Sample Mean<br>(Temp.>=60F) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|----------------------------|-----------------------------|-----------------|------------------------------|
| Mode     | Auto            | 19.51                      | 20.40                       | 4.38            | S                            |
|          | Bus             | 37.32                      | 35.95                       | -3.80           | I                            |
|          | Rail            | 60.84                      | 64.36                       | 5.47            | S                            |
|          | Walk            | 12.82                      | 14.13                       | 9.23            | S                            |
|          | Bike            | 20.65                      | 22.97                       | 10.06           | I                            |
|          | Other           | 92.37                      | 94.97                       | 2.74            | I                            |
| Purpose  | Home            | 22.15                      | 22.35                       | 0.93            | I                            |
|          | Work            | 29.54                      | 28.94                       | -2.06           | I                            |
|          | School          | 18.23                      | 18.60                       | 1.95            | I                            |
|          | Mode-<br>change | 17.10                      | 19.39                       | 11.84           | S                            |
|          | Errands         | 18.07                      | 18.03                       | -0.24           | I                            |
|          | Leisure         | 20.12                      | 23.99                       | 16.14           | S                            |
|          | Other           | 21.61                      | 23.13                       | 6.56            | S                            |
| TOTAL    |                 | 21.19                      | 21.87                       | 3.12            | S                            |

# Snowfall

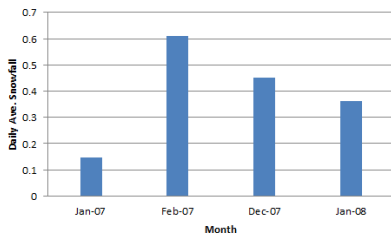


Figure: DAILY AVERAGE SNOWFALL BY MONTH (INCH/DAY)

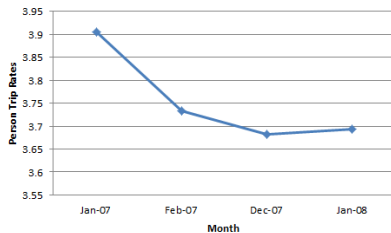


Figure: PERSON TRIP RATES BY MONTH

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

**Snowfall**

Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Snowfall

- ▶ To study the impact of snowfall on the travel behavior, we would eliminate the impact of temperature.
- ▶ Noting the temperature from December to February is relatively stable, we will focus on the sample drawn during this time period.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

**Snowfall**

Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Snowfall

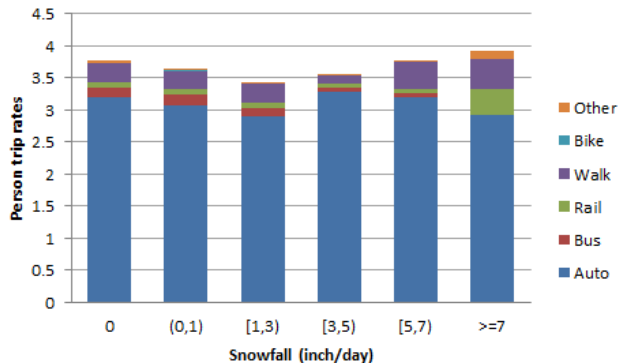


Figure: PERSON TRIP RATES BY DAILY SNOWFALL AND TRAVEL MODES

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

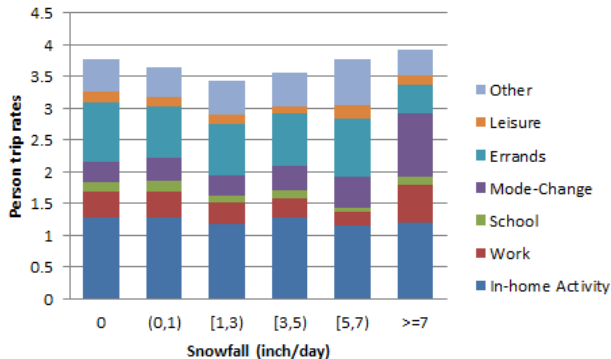
Snowfall

Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Snowfall



**Figure:** PERSON TRIP RATES BY DAILY SNOWFALL AND TRAVEL PURPOSES

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Snowfall

Table: SNOWY DAYS PROPORTION

| COUNTY  | Snowy days (%) | Clear days (%) |
|---------|----------------|----------------|
| Cook    | 18.00          | 82.00          |
| DuPage  | 14.00          | 86.00          |
| Grundy  | 14.00          | 86.00          |
| Kane    | 13.00          | 87.00          |
| Kendall | 15.00          | 85.00          |
| Lake    | 17.00          | 83.00          |
| McHenry | 14.00          | 86.00          |
| Will    | 11.00          | 89.00          |
| Total   | 14.50          | 85.50          |

“Snowy day” is defined to have more than (or equal to) 1 inch snowfall during 24 hours, and the other days are defined as “clear day”.

Table 6: PERSON TRIP RATES BY SNOWFALL

| Variable          | Category | Sample Mean<br>(Snowy) | Sample Mean<br>(Clear) | Decrease<br>(%) | Significance<br>(level 0.05) |
|-------------------|----------|------------------------|------------------------|-----------------|------------------------------|
| Age               | < 20     | 3.02                   | 3.10                   | 2.80            | I                            |
|                   | 20-24    | 3.15                   | 3.35                   | 5.89            | I                            |
|                   | 25-54    | 3.94                   | 4.13                   | 4.65            | I                            |
|                   | 55-64    | 3.73                   | 4.07                   | 8.37            | I                            |
|                   | 65+      | 3.01                   | 3.54                   | 14.86           | S                            |
| Gender            | Male     | 3.49                   | 3.63                   | 3.81            | I                            |
|                   | Female   | 3.49                   | 3.85                   | 9.38            | S                            |
| License<br>Status | Yes      | 3.84                   | 4.10                   | 6.26            | S                            |
|                   | No       | 1.90                   | 2.26                   | 15.78           | S                            |
| Worker<br>Status  | Yes      | 3.96                   | 4.18                   | 5.36            | S                            |
|                   | No       | 2.98                   | 3.36                   | 11.36           | S                            |
| Day               | Weekday  | 3.56                   | 3.79                   | 6.28            | S                            |
|                   | Weekend  | 3.02                   | 3.18                   | 5.06            | I                            |

# Snowfall

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature

**Snowfall**

Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

| Variable | Category        | Sample Mean<br>(Snowy) | Sample Mean<br>(Clear) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|------------------------|------------------------|-----------------|------------------------------|
| Mode     | Auto            | 2.97                   | 3.19                   | 6.85            | S                            |
|          | Bus             | 0.12                   | 0.14                   | 19.24           | S                            |
|          | Rail            | 0.09                   | 0.09                   | -9.65           | I                            |
|          | Walk            | 0.29                   | 0.29                   | 0.92            | I                            |
|          | Bike            | 0.00                   | 0.01                   | 58.51           | S                            |
|          | Other           | 0.03                   | 0.03                   | 5.16            | I                            |
| Purpose  | Home            | 1.19                   | 1.28                   | 7.46            | S                            |
|          | Work            | 0.34                   | 0.40                   | 15.90           | S                            |
|          | School          | 0.10                   | 0.16                   | 35.35           | S                            |
|          | Mode-<br>change | 0.35                   | 0.34                   | -4.20           | I                            |
|          | Errands         | 0.82                   | 0.91                   | 10.38           | S                            |
|          | Leisure         | 0.15                   | 0.16                   | 4.21            | I                            |
|          | Other           | 0.56                   | 0.51                   | -10.76          | S                            |
| TOTAL    |                 | 3.50                   | 3.75                   | 6.61            | S                            |

# Snowfall

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
**Snowfall**  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

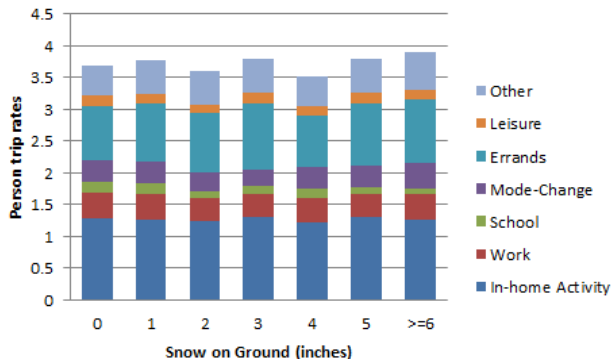
Table 7: AVERAGE TRIP DISTANCE BY SNOWFALL

| Variable | Category        | Sample Mean<br>(Snowy) | Sample Mean<br>(Clear) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|------------------------|------------------------|-----------------|------------------------------|
| Mode     | Auto            | 5.10                   | 5.03                   | -1.49           | I                            |
|          | Bus             | 3.23                   | 3.54                   | 9.00            | I                            |
|          | Rail            | 15.34                  | 15.30                  | -0.25           | I                            |
|          | Walk            | 0.48                   | 0.76                   | 36.38           | S                            |
|          | Bike            | 0.18                   | 1.58                   | 88.38           | S                            |
|          | Other           | 7.79                   | 11.84                  | 34.26           | S                            |
| Purpose  | Home            | 4.95                   | 5.00                   | 0.98            | I                            |
|          | Work            | 8.60                   | 8.44                   | -1.87           | I                            |
|          | School          | 2.48                   | 3.14                   | 20.97           | S                            |
|          | Mode-<br>change | 4.27                   | 4.23                   | -0.79           | I                            |
|          | Errands         | 4.39                   | 4.10                   | -7.02           | I                            |
|          | Leisure         | 4.62                   | 3.93                   | -17.66          | I                            |
|          | Other           | 4.59                   | 4.76                   | 3.57            | I                            |
| TOTAL    |                 | 4.97                   | 4.93                   | -0.69           | I                            |

Table 8: AVERAGE TRIP DURATION BY SNOWFALL

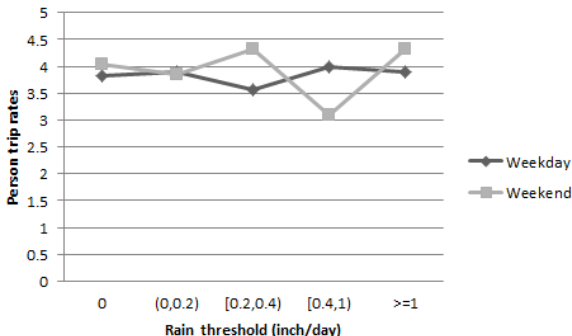
| Variable | Category        | Sample Mean<br>(Snowy) | Sample Mean<br>(Clear) | Decrease<br>(%) | Significance<br>(level 0.05) |
|----------|-----------------|------------------------|------------------------|-----------------|------------------------------|
| Mode     | Auto            | 20.30                  | 18.82                  | -7.87           | S                            |
|          | Bus             | 36.80                  | 36.02                  | -2.18           | I                            |
|          | Rail            | 60.85                  | 63.05                  | 3.49            | I                            |
|          | Walk            | 11.82                  | 11.98                  | 1.34            | I                            |
|          | Bike            | 12.80                  | 17.46                  | 26.70           | I                            |
|          | Other           | 93.28                  | 91.76                  | -1.66           | I                            |
| Purpose  | Home            | 22.52                  | 21.51                  | -4.73           | I                            |
|          | Work            | 31.99                  | 29.37                  | -8.90           | I                            |
|          | School          | 17.85                  | 17.65                  | -1.14           | I                            |
|          | Mode-<br>change | 16.07                  | 16.16                  | 0.57            | I                            |
|          | Errands         | 18.50                  | 17.28                  | -7.05           | I                            |
|          | Leisure         | 25.22                  | 18.74                  | -34.55          | S                            |
|          | Other           | 22.32                  | 21.15                  | -5.53           | I                            |
| TOTAL    |                 | 21.80                  | 20.52                  | -6.24           | S                            |

# Snow on Ground



The snow on ground effect does not have clear correlation with the trip rates.

# Rain



**Figure:** PERSON TRIP RATES BY DAILY RAINFALL AND DAY OF WEEK

The rain did not have a significant effect on the travel behavior.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Outline

## Introduction

## Background

The Travel Tracker Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip Generation Model  
Weather Adjustment Factor

## Summary

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

### Introduction

### Background

The Travel Tracker  
Survey  
Weather Data

### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Modeling Weather Impacts on Trip Generation

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

- ▶ First, a regular trip generation model without considering weather factors will be introduced.
- ▶ Second, a weather adjustment factor will be developed using nonparametric method.
- ▶ The final adjusted model is constructed by combining the regular model and the weather adjustment factor.

Adjusted Trip Rate = Regular Trip Rate  $\times$  Weather  
Adjustment Factor

# Regular Trip Generation Model

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

## Activity Based Trip Generation Model

- ▶ This is a simplified version of the one in New York Best Practice Model (NYBPM).
- ▶ First classify people into three separate groups: workers (age 16 or older, full-time or part-time), non-workers (age 16 or older), and children (age 15 or younger).
- ▶ Second define seven trip purposes including: home related, work related, school related, passenger pick-up/drop-off/mode-change, errands, leisure, and other.
- ▶ Then a multinomial model is fitted for each population group and each purpose.

# Regular Trip Generation Model

The multinomial model is defined as following:

$$P^{ut}(i) = \frac{\exp(V_i^{ut})}{\sum_{j=1}^3 \exp(V_j^{ut})}, \text{ for } i = 0, 1, 2, 3$$

where:

- ▶  $i, j = 0, 1, 2, 3$ : choice alternatives (number of trips implemented by the person). 3 stands for 3 trips or more.
- ▶  $u = 1, 2, 3, 4, 5, 6, 7$ : trip purposes.
- ▶  $t = 1, 2, 3$ : population group the person belongs to.
- ▶  $P^{ut}(i)$ : probability of each alternative to be chosen.
- ▶  $V_i^{ut}$ : utility function.

# Regular Trip Generation Model

The form of utility function  $V_i^{ut}$  is given below:

$$V_i^{ut} = \alpha_i^{ut} + \beta_i^{1ut} x_1 + \beta_i^{2ut} x_2 + \beta_i^{3ut} x_3 + \beta_i^{4ut} x_4 + \beta_i^{5ut} x_5$$

where:

- ▶  $\alpha_i^{ut}$ : estimated constants.
- ▶  $\beta_i^{kut}$ : estimated coefficients for person-specific variables.
- ▶  $x_1$ : household size.
- ▶  $x_2$ : number of workers in the household.
- ▶  $x_3$ : number of vehicles in the household .
- ▶  $x_4$ : household income.
- ▶  $x_5$ : driver license status.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Weather Adjustment Factor

Mahmassani, et al. (2009) made adjustment to the traffic flow model by introducing a linear weather adjustment factor (WAF), as follows (the original weather variables used are visibility, rain, and snow, here we use temperature and snow):

$$F(t, s) = \gamma_0 + \gamma_1 t + \gamma_2 s + \gamma_3 ts$$

where

- ▶  $F(t, s)$ : weather adjustment factor.
- ▶  $\gamma_i$  :  $i = 1, 2, 3$ : estimated coefficients for weather variables.
- ▶  $t$ : daily average temperature.
- ▶  $s$ : daily snowfall amount.

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Weather Adjustment Factor

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Then the traffic flow rate under inclement weather is calculated as follows:

$$f' = F(t, s)f \quad (1)$$

where

- ▶  $f'$ : traffic flow under inclement weather.
- ▶  $F$ : weather adjustment factor.
- ▶  $f$ : traffic flow under clear weather.

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

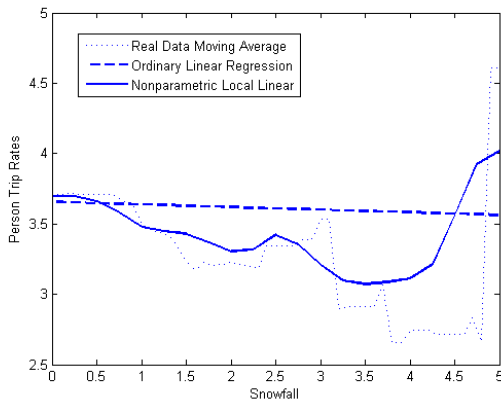
Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Weather Adjustment Factor

However, in the case considered here, the linear function form cannot represent the weather impact accurately. By contrast, the nonparametric approach (Local-Linear Mean Regression) has better performance.



**Figure:** Comparison Nonparametric Local Linear Regression VS. Ordinary Linear Regression by regressing daily person trip rates on the snowfall

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

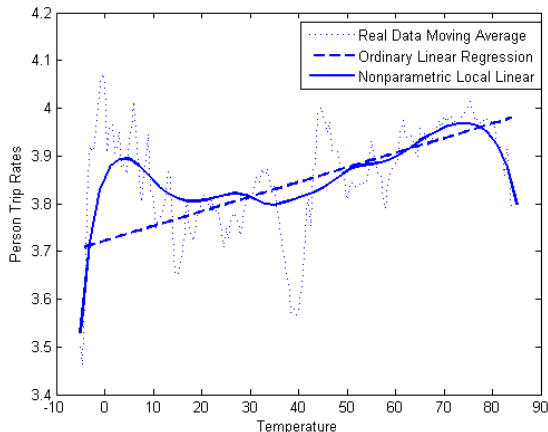
Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Weather Adjustment Factor



**Figure:** Comparison Nonparametric Local Linear Regression VS. Ordinary Linear Regression by regressing daily person trip rates on the temperature

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Local-Linear Mean Regression

By Local-Linear Mean Regression, the estimated person trip rate  $T_{LL}$  takes the form of

$$T_{LL}(t, s) = [A^{-1} \times B]_{(1,1)}$$

where  $A$  is a  $3 \times 3$  matrix,  $B$  is a  $3 \times 1$  vector,  $(1, 1)$  indicates the element in first row and first column in matrix  $A^{-1} \times B$ .  $A$  and  $B$  are defined below:

$$A = \sum_{i=1}^n [1, t_i - t, s_i - s]' \times [1, t_i - t, s_i - s] \times K\left(\frac{t_i - t}{h_t}, \frac{s_i - s}{h_s}\right)$$

$$B = \sum_{i=1}^n Y_i \times [1, t_i - t, s_i - s]' \times K\left(\frac{t_i - t}{h_t}, \frac{s_i - s}{h_s}\right)$$

and  $K$  is a kernel function with support on  $[-1, 1] \times [-1, 1]$ :

$$K(x, y) = \left(\frac{15}{16}\right)^2 \times (1 - x^2)^2 \times (1 - y^2)^2$$

# Performance

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

**Table:** Model Evaluation for Snowy Days

| Model | Original | Adjusted -1 | Adjusted -2 |
|-------|----------|-------------|-------------|
| Bias  | 0.2334   | 0.1126      | 0.0512      |
| MSE   | 7.3232   | 7.2540      | 7.0246      |

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Performance

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

**Table:** Model Evaluation for Winter Days

| Model | Original | Adjusted -1 | Adjusted -2 |
|-------|----------|-------------|-------------|
| Bias  | 0.1074   | -0.0205     | -0.0578     |
| MSE   | 7.0921   | 7.0784      | 7.0862      |

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Performance

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

Table: Model Evaluation for Summer Days

| Model | Original | Adjusted -1 | Adjusted -2 |
|-------|----------|-------------|-------------|
| Bias  | -0.2046  | -0.1195     | -0.1277     |
| MSE   | 8.5321   | 8.5083      | 8.5086      |

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Outline

## Introduction

## Background

The Travel Tracker Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip Generation Model  
Weather Adjustment Factor

## Summary

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.n

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

## Introduction

## Background

The Travel Tracker  
Survey  
Weather Data

## Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

## Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

# Summary

The Weather  
Impact on Travel  
Behavior in  
Chicagoland

Zhenyu Zhao

zhenyuzhao2014@u.i.

Department of  
Statistics  
Northwestern  
University

Internship at  
CMAP Apr. - Jun.  
2011

- ▶ In general, the temperature and snowfall have significant impact on travel behavior.
- ▶ The weather impact is nonlinear with respect to trip rates.
- ▶ By including the weather adjustment factor, the model accuracy can be improved. Especially, the weather adjustment factor has bias correction effect.

Introduction

Background

The Travel Tracker  
Survey  
Weather Data

Weather Impacts  
on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

Modeling Weather  
Impacts on Trip  
Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor

THANK YOU!

#### Introduction

#### Background

The Travel Tracker  
Survey  
Weather Data

#### Weather Impacts on travel behavior

Temperature  
Snowfall  
Snow on Ground  
Rain

#### Modeling Weather Impacts on Trip Generation

Regular Trip  
Generation Model  
Weather Adjustment  
Factor