Multifaceted Approach Integrating Mobility, Safety, Air Quality, Physical Activity, and Public Health

Shinhye Joo
Department of Civil and Construction Engineering
Western Michigan University

Jun-Seok Oh
Department of Civil and Construction Engineering
Western Michigan University
INTRODUCTION

Leading Causes of Death (2015 U.S.)

- Heart Diseases: 23.4%
- Cancer: 22.0%
- Lung Diseases: 5.7%
- Accidents: 5.4%
- Stroke: 5.2%
- Alzheimer's Diseases: 4.1%

Vehicle Emissions
Vehicle Crashes

https://www.cdc.gov/injury/wisqars/LeadingCauses.html
## INTRODUCTION

### Leading Causes of Death by Age

<table>
<thead>
<tr>
<th>Rank</th>
<th>&lt;1</th>
<th>1-4</th>
<th>5-9</th>
<th>10-14</th>
<th>15-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>55-64</th>
<th>65+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Congenital Anomalies</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Malignant Neoplasms</td>
<td>Malignant Neoplasms</td>
<td>Malignant Neoplasms</td>
<td>Heart Disease</td>
<td>Heart Disease</td>
</tr>
<tr>
<td>2</td>
<td>Short Gestation</td>
<td>SIDS</td>
<td>Malignant Neoplasms</td>
<td>Malignant Neoplasms</td>
<td>Suicide</td>
<td>Suicide</td>
<td>Malignant Neoplasms</td>
<td>Heart Disease</td>
<td>Heart Disease</td>
<td>Malignant Neoplasms</td>
<td>Malignant Neoplasms</td>
</tr>
<tr>
<td>3</td>
<td>Homicide</td>
<td>Congenital Anomalies</td>
<td>Suicide</td>
<td>Homicide</td>
<td>Homicide</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Unintentional Injury</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Chronic Low. Respiratory Disease</td>
</tr>
<tr>
<td>4</td>
<td>Malignant Neoplasms</td>
<td>Homicide</td>
<td>Homicide</td>
<td>Malignant Neoplasms</td>
<td>Suicide</td>
<td>Liver Disease</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Cerebrovascular</td>
<td>Unintentional Injury</td>
<td>Chronic</td>
</tr>
<tr>
<td>5</td>
<td>Unintentional Injury</td>
<td>Heart Disease</td>
<td>Heart Disease</td>
<td>Congenital Anomalies</td>
<td>Heart Disease</td>
<td>Heart Disease</td>
<td>Malignant Neoplasms</td>
<td>Suicide</td>
<td>Diabetes Mellitus</td>
<td>Alzheimer’s Disease</td>
<td>Cerebrovascular</td>
</tr>
<tr>
<td>6</td>
<td>Placebo Cord Membranes</td>
<td>Influenza &amp; Pneumonia</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Heart Disease</td>
<td>Congenital Anomalies</td>
<td>Liver Disease</td>
<td>Diabetes Mellitus</td>
<td>Cerebrovascular</td>
<td>Unintentional Injury</td>
<td>Diabetes Mellitus</td>
<td>Alzheimer’s Disease</td>
</tr>
<tr>
<td>7</td>
<td>Bacterial Sepsis</td>
<td>Septicemia</td>
<td>Influenza &amp; Pneumonia</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Diabetes Mellitus</td>
<td>Diabetes Mellitus</td>
<td>Cerebrovascular</td>
<td>Unintentional Injury</td>
<td>Diabetes Mellitus</td>
<td>Influenza &amp; Pneumonia</td>
</tr>
<tr>
<td>8</td>
<td>Respiratory Distress</td>
<td>Prenatal Period</td>
<td>Cerebrovascular</td>
<td>Cerebrovascular</td>
<td>Diabetes Mellitus</td>
<td>Cerebrovascular</td>
<td>Chronic Low. Respiratory Disease</td>
<td>Suicide</td>
<td>Influenza &amp; Pneumonia</td>
<td>Influenza &amp; Pneumonia</td>
<td>Nephritis</td>
</tr>
<tr>
<td>9</td>
<td>Circulatory System Disease</td>
<td>Cerebrovascular</td>
<td>Benign Neoplasms</td>
<td>Influenza &amp; Pneumonia</td>
<td>Influenza &amp; Pneumonia</td>
<td>HIV</td>
<td>Septicemia</td>
<td>Septicemia</td>
<td>Nephritis</td>
<td>Nephritis</td>
<td>Septicemia</td>
</tr>
<tr>
<td>10</td>
<td>Neonatal Hemorrhage</td>
<td>Chronic Low Respiratory Disease</td>
<td>Septicemia</td>
<td>Two Tied: Benign Neo./Septicemia</td>
<td>Cerebrovascular</td>
<td>Congenital Anomalies</td>
<td>Septicemia</td>
<td>Nephritis</td>
<td>Septicemia</td>
<td>Suicide</td>
<td>Suicide</td>
</tr>
</tbody>
</table>

https://www.cdc.gov/injury/wisqars/LeadingCauses.html
INTRODUCTION

- Objectives

Need to traffic management strategies for promoting “public health” and “traffic safety”

Multifaceted approach Transportation System Evaluation

Network Performance  Traffic Safety  Environmental impact  Physical Activity
### METHODOLOGY

**Overall Framework**

<table>
<thead>
<tr>
<th>Data source</th>
<th>Performance evaluation</th>
<th>Integrated index for assessing transportation performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDS or simulated data</td>
<td>Average speed, Average delay,</td>
<td>TPH* index = f(Delay cost, METs, Crash, Concentration of pollutant)</td>
</tr>
<tr>
<td>Household survey or estimated data</td>
<td>Percent of PA trips, METs</td>
<td>* TPH : Transportation Performance Index</td>
</tr>
<tr>
<td>Crash record or modeled/simulated data</td>
<td>Number of crashes, Fatalities, conflicts..</td>
<td></td>
</tr>
<tr>
<td>Air pollutant concentration record or estimated data</td>
<td>Concentration of PM$_{2.5}$, O$_3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Network Performance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physical Activity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Traffic Safety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air quality</td>
<td></td>
</tr>
</tbody>
</table>

Methodology
- Using Normalization
METHODOLOGY

Candidate Performance Measures

- Mobility or Network Performance
  - Average travel speed
  - Average delay
  - Travel time
METHODOLOGY | Candidate Performance Measures

- **Traffic Safety Performance**
  - Number of Crashes
  - Number of conflicts

*TMC: Transportation Management Center*
**METHODOLOGY**

**Candidate Performance Measures**

**Air Quality Evaluation**

- Concentration of pollutant \( \mu g/m^3 \)
  - Particle Matter (PM\(_{2.5}\) )

![Diagram showing air pollution and health impacts](image)

- Eyes irritation
- Nose irritation
- Throat irritation
- Cardiovascular diseases
- Lung problems, even lung cancer

Enter through nose and mouth.
Larger particles such as PM10 are eliminated through coughing, sneezing, and swallowing.
Smaller PM2.5 particles can travel deeper, causing lung and heart problems.
METHODOLOGY |
Candidate Performance Measures

Physical Activity Assessment

- Metabolic equivalents (METs) hours
  - METs are a ratio between the metabolic rate of an activity in relation to the resting metabolic rate.
  - Many studies showed the relationship between METs hour and health impact such as all-cause mortality.

METHODOLOGY

- Data Source and Preparation

- MDOT Congestion and Mobility report
- MDOT Household survey
- MDOT crash record
- DEQ Air quality monitoring data

Network Performance
Traffic Safety
Environmental impact
Physical Activity
**METHODOLOGY**

- **Transportation Performance Index (TPH index)**
  
  - \( \Phi(z) = P(Z \leq z) = f(z; \mu, \sigma) \)
  
  - TPH index = \( \Phi_{i} (z_{i}) + \{1 - \Phi_{j} (z_{j})\} + \Phi_{k} (z_{k}) + \Phi_{l} (z_{l}) \)

  - \( \Phi(z) \): cumulative percentage,
  - \( z \): value of performance measure
  - \( \mu \): the average
  - \( \sigma \): the standard deviation
  - \( i, j, k, l \) stand for each performance measure of mobility or network performance, traffic safety, air quality, and physical activity.
Comparison of Transportation Performance in Michigan
### CASE STUDY

**Comparison of Transportation Performance in Michigan**

<table>
<thead>
<tr>
<th>Region</th>
<th>Network Performance</th>
<th>Physical activity</th>
<th>Traffic Safety</th>
<th>Air quality</th>
<th>TPH index*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay costs ($/mile^2)</td>
<td>METs (hr/ mile^2)</td>
<td>Crash numbers (cases/ mile^2)</td>
<td>Concentration of O₃ (ppm)</td>
<td></td>
</tr>
<tr>
<td>Bay (28,246 miles^2)</td>
<td>Mean 12.85  Φ(z) 0.36</td>
<td>Mean 0.17  Φ(z) 0.63</td>
<td>Mean 1.51  Φ(z) 0.32</td>
<td>Mean 0.0675  Φ(z) 0.50</td>
<td>1.46</td>
</tr>
<tr>
<td>Grand (21,216 miles^2)</td>
<td>Mean 14.59  Φ(z) 0.37</td>
<td>Mean 0.13  Φ(z) 0.69</td>
<td>Mean 2.33  Φ(z) 0.36</td>
<td>Mean 0.0697  Φ(z) 0.90</td>
<td>1.94</td>
</tr>
<tr>
<td>Metro (5,029 miles^2)</td>
<td>Mean 140.26  Φ(z) 0.96</td>
<td>Mean 0.13  Φ(z) 0.69</td>
<td>Mean 23.36  Φ(z) 0.98</td>
<td>Mean 0.0674  Φ(z) 0.48</td>
<td>2.14</td>
</tr>
<tr>
<td>North (28,982 miles^2)</td>
<td>-</td>
<td>Mean 0.14  Φ(z) 0.68</td>
<td>Mean 0.64  Φ(z) 0.29</td>
<td>Mean 0.0663  Φ(z) 0.25</td>
<td>1.22</td>
</tr>
<tr>
<td>Southwest (10,261 miles^2)</td>
<td>Mean 2.60  Φ(z) 0.29</td>
<td>Mean 0.19  Φ(z) 0.60</td>
<td>Mean 2.49  Φ(z) 0.36</td>
<td>Mean 0.0690  Φ(z) 0.81</td>
<td>1.77</td>
</tr>
<tr>
<td>University (14,531 miles^2)</td>
<td>Mean 3.76  Φ(z) 0.30</td>
<td>Mean 0.73  Φ(z) 0.02</td>
<td>Mean 3.07  Φ(z) 0.39</td>
<td>Mean 0.0650  Φ(z) 0.07</td>
<td>0.48</td>
</tr>
<tr>
<td>Data source</td>
<td>MDOT Congestion and Mobility report</td>
<td>MDOT Household survey</td>
<td>MDOT crash record</td>
<td>DEQ Air quality monitoring data</td>
<td></td>
</tr>
</tbody>
</table>

* TPH index does not include the network performance in this case due to the lack of data in the North region
The Metro region had larger values with respect to network performance, traffic safety, and physical activity compared to other regions.

Therefore, the region may need strategies to enhance traffic safety and to promote physical activity.

The Grand and South regions presented similar characteristics. They also had higher values in air quality, which means that the ozone concentrations in these two regions were high.
DISCUSSION

### Procedure of simulation-based assessment

<table>
<thead>
<tr>
<th>Assessment item</th>
<th>Input data</th>
<th>Analysis tool</th>
<th>Performance measures</th>
<th>Additional analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Network Performance</td>
<td>Traffic data, Geometric data, Traffic pattern</td>
<td>TRANSIMs, TransCAD, VISSIM</td>
<td>Speed, delay, volume,</td>
<td>Number of fatalities</td>
</tr>
<tr>
<td>2 Traffic safety</td>
<td>Traffic data, Geometric data, Traffic pattern</td>
<td>TRANSIMs, TransCAD, VISSIM</td>
<td>Number of conflicts, conflict severity, Number of crashes</td>
<td>Number of exposure population</td>
</tr>
<tr>
<td>3 Air quality/Environmental impact</td>
<td>MM5, Emission Rate, Geometric data, Land use data</td>
<td>CALPUFF, AREMOD, CALINE</td>
<td>Concentration of air pollutants</td>
<td>Number of exposure population</td>
</tr>
<tr>
<td>4 Physical activity</td>
<td>Traffic data, Geometric data, Traffic pattern</td>
<td>TRANSIMs, TransCAD, VISSIM</td>
<td>METs, Mortality rate</td>
<td>Health Impact, Economic cost</td>
</tr>
</tbody>
</table>

TPH index
Conclusion

• This study proposed a conceptual assessment framework of multifaceted transportation performances integrating mobility, safety, air quality, and physical activity.

• The framework provides each of individual performance measures as well as the transportation performance index (TPH index).

• The proposed integrated evaluation framework was applied to the case of Michigan as an example.

• The results of the proposed method can be an effective decision supporting tool in analyzing traffic management strategies.
CONCLUSION

Further study

- Various strategies and simulated data should be applied in order to verify and calibrate the comprehensive framework.
- Extensive analyses should be performed to determine the contributing factors.
[ Thank you ]

Shinhye Joo
Department of Civil and Construction Engineering
Western Michigan University
Email: shinhye.joo@wmich.edu