ITS and Sustainability
Outline

Introduction

Motivation

Key Factors

Monitoring

Roads and environment impact
  • Traffic meteorology vs air quality
  • Pollutant
  • Concentration changes vs distance from road
  • Wind tunnel assessments
  • Noise barrier and vegetation effects

Modeling

How ITS can help the environment
  • Eco-driving
  • Traffic management and control
  • Fleet management
  • Freight
  • Transit
INTRODUCTION
Definition

• An overarching conceptual framework that describes a desirable, healthy, and dynamic balance between human and natural systems.

Triple Bottom Line
Motivation

• Most of the population live within 100 meters of major transportation roads and highways.

• More then 1000 compounds have been detected in our air.
  – Air toxics
  – Particulate Matter
  – Etc

• Air quality measurement have indicated elevated pollutant concentrations near roads.
Motivation

- Living near roads have been associated with adverse health endpoints
  - Cardio-respiratory effects (e.g., asthma, bronchitis)
  - Adverse birth outcomes/developmental effects
  - Cardiovascular effects
Key factors

• Aims for near road monitoring
• Data measurements
  – Air quality
  – Meteorology
  – Traffic status and activity
• Network design
Monitoring

- Traffic status and activity
  - Traffic volume, fleet, speed

- Meteorology
  - Wind direction, wind speed, temperature, humidity
  - Vehicle introduce turbulence that can affect meteorology

- Air quality
  - Pollutants of interest
    - CO, NO/NO2/Nox, Pb, …
  - Frequency measurement
    - Shortest averaging times generally most desirable to determine relationships among traffic, meteorology and air quality
ROADS AND ENVIRONMENT IMPACT
Traffic Meteorology and air quality

Source: EPA US environment protection agency
Pollutant

Source: EPA US environment protection agency
Concentration Changes with Distance from Road

Source: EPA US environment protection agency
Wind Tunnel Assessments: Roadway Design

Flat terrain

Up and downwind sound barriers

Depressed roadway, vertical walls

Depressed roadway, sloped walls

Source: EPA US environment protection agency
Wind Tunnel Assessments: Roadway Design

Source: EPA US environment protection agency
Wind Tunnel Assessments: Roadway Design

Source: EPA US environment protection agency
Noise Barrier and Vegetation Effects

Source: EPA US environment protection agency
Noise Barrier and Vegetation Effects

Source: EPA US environment protection agency
Modeling air pollution

• One of the technique is using Advection Diffusion Equation

\[
\frac{\partial C}{\partial t} = -(U \cdot \nabla)C + K_D \nabla^2 C + S
\]

- \(C(x,y,z,t)\) = concentration of pollutant
- \(K_D(x,y,z,t)\) = atmospheric turbulent diffusion coefficient
- \(U(x,y,z,t)\) = wind speed vector
- \(S(x,y,z,t)\) = source/sink for pollutant
- \(\nabla\) = gradient operator
- \(\nabla^2\) = Laplacian operator
Modeling air pollution

• Example
  – “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
  – Hope Street, Glasgow
Wind Rose for Meteorological Office Weather Station at Bishopton

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
Typical Wind Speed Distribution for Bishopton Weather Station

Weibull Distribution: 270 deg. Sector

Wind Speed (m/s) vs. Probability Density (s/m)

Alpha = 1.51, Beta = 5.03

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
PHOENICS two-dimensional simulated wind flow in a street canyon for $W=30$ m, $H=20$ m.

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
PHOENICS two-dimensional simulated wind flow in a street canyon for \(W=40 \text{ m}, H=5 \text{ m}\)

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
PHOENICS CO contours (ppm) for a wind speed above building $U=5 \text{ m s}^{-1}$, $W=30 \text{ m}$, $H=20 \text{ m}$

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
PHOENICS CO contours (ppm) for a wind speed above building $U=5 \text{ m s}^{-1}$, $W=40 \text{ m}$, $H=5 \text{ m}$

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
Wind Field for AutoCAD Solid Model of Glasgow LAQM Area

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
SUMO Tool

- CO₂ Emission Models
  - Handbook of Emission Factors for Road Traffic Model (HBEFA) - Versions 2.1 & 3.1
    - Vehicle category: passenger cars, light duty vehicles, heavy duty vehicles, buses, coaches and motorcycles
    - Pollutants covered - CO₂, CO, HC, NOₓ, PMₓ
  - Passenger car and Heavy duty Emission Model (PHEMlight)
    - Pollutants covered - CO₂, CO, HC, NOₓ, PMₓ
Typical CO Conc. Field, Red=High Blue=Low

Source: “The Application of CFD to the Estimation of Motor Vehicle Pollution in Urban Environments” by Prof. John M. Crowther
Eco-driving

• The aim is to promote a driving style that will lower the vehicles emissions.

• Through:
  – Eco-Routing Navigation
  – Eco-Driving assistance
  – Adaptive Cruise Control (ACC)
Eco-driving

• Impact
  – Eco-Routing Navigation (reducing emission by 15 %)
  – Eco-Driving assistance (reducing emission by 15 %)
  – Adaptive Cruise Control (reducing emission by 10%)
Traffic Management and control

• Gives the ability to analyze the traffic status and dynamically adjust it to different type of traffic.

  - Incident Management Systems
  - Ramp Metering
  - Speed Management
  - Signal Coordination & Optimization
  - Adaptive Signal Control
Traffic Management and control

• Impact:

- Incident Management Systems
- Ramp Metering
- Speed Management
- Signal Coordination & Optimization
- Adaptive Signal Control

Reduce emission by

- 3%
- 3% to 8%
- 17% to 25%
- 50% or increase it by 9%
- 22%
Fleet Management

- Optimization of routing, speed, vehicle maintenance, and fuel management

Automated Vehicle Location (AVL) Systems

Idle-Off Stop-Start Systems

- AT A STOP: The gas engine remains dormant when the vehicle is at rest.
- STARTING: The starter-generator pulls electricity from batteries to start gas engine.
- CHARGING: Starter-generator converts gas from engine into electricity in the battery.
- STOPPING: Regenerative braking converts energy into electricity, in some stop-start cars.
Fleet Management

• Impact:

Automated Vehicle Location (AVL) Systems

- Can assist in optimizing routes, which can reduce Vehicle miles traveled, and therefore, emissions

Idle-Off Stop-Start Systems

- Can reduce emissions up to 20% in urban environments, and idle reduction technologies for freight rest stops have demonstrated the ability to reduce emissions by 83%.
Freight

• Reduce freight emissions through the exchange of information that allows for more efficient management of freight travel and delivery.
Freight

• Impact:

Platooning

Delivery Management

Freight Eco-Driving

10% to 20%

United Parcel Service (UPS) delivery management initiatives have helped the company to reduce fuel consumption by 3 million gallons and eliminate 32,000 MTCE per year.

5% to 20%
Transit

• Reduce transit emissions through the exchange of information that allows for optimization of transit travel and mode shift.

Transit Signal Priority (TSP)  
Bus Rapid Transit (BRT)
• Impact

Transit Signal Priority (Reduce up to 30%)

Bus Rapid Transit (Reduce up to 25%)
Urban livability

Class Activity:
- Select a Team mate
- Select one the strategic development areas
- Identify the major problem face by this strategic area
- Propose a smart, innovative and feasible solution